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CLAIMS					
	NO. OF CLAIMS		EXTRA CLAIMS	RATE	FEE
Basic Application Fee					\$690.00 (101)
Total Claims	26	MINUS 20 =	6	x \$18.00 (103)	108.00
Independent Claims	2	MINUS 3 =	0	x \$78.00 (102)	0.00
If multiple dependent claims are presented, add \$260.00 (104)					
Total Application Fee					\$798.00
If verified Statement claiming small entity status is enclosed, subtract 50% of Total Application Fee					\$399.00
Add Assignment Recording Fee if Assignment document is enclosed					
TOTAL APPLICATION FEE DUE					\$399.00

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TITLE OF THE INVENTION

IDENTIFICATION OF UNIQUE BINDING INTERACTIONS BETWEEN CERTAIN ANTIBODIES AND THE HUMAN B7.1 AND B7.2 CO-STIMULATORY ANTIGENS

RELATED APPLICATIONS

This application is a continuation-in-part of U.S. Application Serial No. 08/746,361, filed November 8, 1996, in turn a continuation-in-part of U.S. application Serial No. 08/487,550, filed June 7, 1995, both of which are incorporated by reference in their entirety herein..

FIELD OF THE INVENTION

The present invention relates to the identification and use of monoclonal antibodies which are specific to B7.1 antigens (CD80). More specifically, the present invention relates to the identification and use of monoclonal antibodies or primatized forms thereof which are capable of inhibiting the binding of human B7.1 antigen to a CD28 receptor and which are not capable of inhibiting the binding of B7.1 to a CTLA-4 receptor. Thus, the invention relates to the identification and use of monoclonal antibodies and primatized forms thereof which recognize specific sites on the B7.1 antigen which are exclusive of CTLA-4 receptor binding.

The invention further relates to monoclonal antibodies or primatized forms thereof which recognize specific sites on the human B7.1 antigen and are capable of inhibiting IL-2 production.

Also, the present invention relates to pharmaceutical compositions containing monoclonal or primatized antibodies specific to human B7.1 and their use as immunosuppressants by modulating the B7:CD28 pathway, e.g., for the treatment of autoimmune disorders, and the prevention of organ rejection.

BACKGROUND OF THE INVENTION

The clinical interface between immunology, hematology, and oncology has long been appreciated. Many conditions treated by the hematologist or oncologist have either an autoimmune or immuno-deficient component to their pathophysiology that has led to the widespread adoption of immunosuppressive medications by hematologists, whereas oncologists have sought immunologic adjuvants that might enhance endogenous immunity to tumors. To date, these interventions have generally consisted of nonspecific modes of immunosuppression and immune stimulation. In addition to the limited efficacy of these interventions, toxicities secondary to their nonspecificity have also limited their overall success. Therefore, alternative strategies have been sought.

Elucidation of the functional role of a rapidly increasing number of cell surface molecules has contributed greatly to the integration of immunology with clinical hematology and oncology. Nearly 200 cell surface antigens have been identified on cells of the immune and hematopoietic systems (Schlossman SF, Boumsell L, Gilks JM, Harlan T, Kishimoto, C Morimoto C, Ritz J., Shaw S, Silverstein RL, Springer TA, Tedder TF, Todd RF:CD antigens (1993), *Blood* 83:879, 1994). These antigens represent

both lineage-restricted and more widely distributed molecules involved in a variety of processes, including cellular recognition, adhesion, induction and maintenance of proliferation, cytokine secretion, effector function, and even cell death. Recognition of the functional attributes of these molecules has fostered novel attempts to manipulate the immune response. Although molecules involved in cellular adhesion and antigen-specific recognition have previously been evaluated as targets of therapeutic immunologic intervention, recent attention has focused on a subgroup of cell surface molecules termed co-stimulatory molecules (Bretscher P: "The two-signal model of lymphocyte activation twenty-one years later." *Immunol. Today* 13:73 (1992); Jenkins MK, Johnson JG: "Molecules involved in T-cell co-stimulation." *Curr Opin Immunol* 5:351 (1993); Geppert T, Davis L. Gur H. Wacholtz M. Lipsky P: "Accessory cell signals involved in T-cell activation." *Immunol Rev* 117:5 (1990); Weaver CT, Unanue ER: "The co-stimulatory function of antigen-presenting cells." *Immunol Today* 11:49 (1990); Stennam RM, Young JW: "Signals arising from antigen-presenting cells." *Curr Opin Immunol* 3:361 (1991)).

Co-stimulatory molecules do not initiate but rather enable the generation and amplification of antigen-specific T-cell responses and effector function (Bretscher P: "The two-signal model of lymphocyte activation twenty-one years later." *Immunol. Today* 13:73 (1992); Jenkins MK, Johnson JG: "Molecules involved in T-cell co-stimulation." *Curr Opin Immunol* 5:351 (1993); Geppert T, Davis L. Gur H. Wacholtz M. Lipsky P: "Accessory cell signals involved in T-cell activation." *Immunol Rev* 117:5 (1990);

Weaver CT, Unanue ER: "The co-stimulatory function of antigen-presenting cells." *Immunol Today* 11:49, (1990); Stennam RM, Young JW: "Signals arising from antigen-presenting cells." *Curr Opin Immunol* 3:361 (1991); June CH, Bluestone JA, Linsley PS, Thompson CD: "Role of the CD28 receptor in T-cell activation." *Immunol Today* 15:321 (1994)).

Recently, one specific co-stimulatory pathway termed B7:CD28 has been studied by different research groups because of its significant role in B- and T-cell activation (June CH, Bluestone JA, Linsley PS, Thompson CD: "Role of the CD28 receptor in T-cell activation." *Immunol Today* 15:321 (1994); June CH, Ledbetter JA: "The role of the CD28 receptor during T-cell responses to antigen." *Annu Rev Immunol* 11:191 (1993); Schwartz RH: "Co-stimulation of T lymphocytes: The role of CD28, CTLA-4, and B7/BB1 in interleukin-2 production and immunotherapy." *Cell* 71:1065-1068 (1992); Jenkins MK, Taylor PS, Norton SD, Urdahl KB: "CD28 delivers a co-stimulatory signal involved in antigen-specific IL-2 production by human T cells." *Journal of Immunology* 147:2461-2466 (1991)). Since this ligand:receptor pathway was discovered four years ago, a large body of evidence has accumulated suggesting that B7:CD28 interactions represent one of the critical junctures in determining immune reactivity versus anergy (June CH, Bluestone JA, Linsley PS, Thompson CD: "Role of the CD28 receptor in T-cell activation." *Immunol Today* 15:321 (1994); June CH, Ledbetter JA: "The role of the CD28 receptor during T-cell responses to antigen." *Annu Rev Immunol* 11:191 (1993);

Schwartz RH: "Co-stimulation of T lymphocytes: The role of CD28, CTLA-4, and B7/BB1 in interleukin-2 production and immunotherapy." *Cell* 71:1065-1068 (1992); Cohen J: "Mounting a targeted strike on unwanted immune responses" (news; comment). *Science* 257:751 (1992); Cohen J: "New protein steals the show as 'co-stimulator' of T cells" (news; comment). *Science* 262:844 (1993)).

In particular, the role of the human B7 antigens, i.e., human B7.1 (CD80) and B7.2 (CD86), has been reported to play a co-stimulatory role in T-cell activation. See, e.g., Gimmi CD, Freeman, GJ, Gribben JG, Sugita K, Freedman AS, Morimoto C, Nadler LM: "B-cell surface antigen B7 provides a costimulatory signal that induces T cells to proliferate and secrete interleukin 2." *Proc. Natl. Acad. Sci. (USA)* 88:6575-6579 (1991).

1. B7.1 and B7.2 Co-stimulatory Role in T Cell Activation

The elaboration of a successful immune response depends on a series of specific interactions between a T cell and an antigen presenting cell. Although the essential first step in this process depends upon the binding of antigen to the T cell receptor, in the context of the MHC class II molecule (Lane, P.J.L., F.M. McConnell, G.L. Schieven, E.A. Clark, and J.A. Ledbetter, (1990), "The Role of Class II Molecules in Human B Cell Activation." *The Journal of Immunology* 144:3684-3692), this interaction alone is not sufficient to induce all the events necessary for a sustained response to a given antigen (Schwartz, R.H. (1990), "A Cell Culture Model for T Lymphocyte Clonal Anergy." *Science* 248:1349; Jenkins, M.K. (1992), "The Role of Cell Division in the Induction of

Clonal Anergy." *Immunology Today* 13:69; Azuma, M., M. Cayabyab, D. Buck, J.H. Phillips, and L.L. Lanier (1992), "Involvement of CD28 in MHC-unrestricted Cytotoxicity Mediated by a Human Natural Killer Leukemia Cell Line." *The Journal of Immunology* 149:1115-1123; Azuma, M., M. Cayabyab, D. Buck, J.H. Phillips, and L.L. Lanier (1992), "CD28 Interaction with B7 Costimulates Primary Allogeneic Proliferative Responses and Cytotoxicity Mediated by Small Resting T Lymphocytes." *J. Exp. Med.* 175:353-360); S.D. Norton, L. Zuckerman, K.B. Urdahl, R. Shefner, J. Miller, and M.K. Jenkins (1992), "The CD28 Ligand, B7, Enhances IL-2 Production by Providing a Costimulatory Signal to T Cells." *The Journal of Immunology* 149:1556-1561; R. H. Schwartz (1992), "Costimulation of T Lymphocytes: The Role of CD28, CTLA-4, and B7/BB1 in Interleukin-2 Production and Immunotherapy." *Cell* 71:1065-1068).

The involvement of certain other co-stimulatory molecules is necessary (Norton, S.D., L. Zuckerman, K.B. Urdahl, R. Shefner, J. Miller, and M.K. Jenkins (1992), "The CD28 Ligand, B7, Enhances IL-2 Production by Providing A Costimulatory Signal to T Cells." *The Journal of Immunology* 149:1556-1561)). "The homodimers CD28 and CTLA-4 expressed on T cells" (June, C.H., J.A. Ledbetter, P.S. Linsley, and C.B. Thompson (1990), "Role of the CD28 Receptor in T-Cell Activation." *Immunology Today* 11:211-216; Linsley, P.S., W. Brady, M. Urnes, L.S. Grosmaire, N.K. Damle, and J.A. Ledbetter (1991), "CTLA-4 is a Second Receptor for the B Cell Activation Antigen B7." *J. Exp. Med.* 174:561)), together with B7.1 (CD80) and B7.2 (CD86) expressed on

antigen presenting cells, are major pairs of co-stimulatory molecules necessary for a sustained immune response (Azuma, M., H. Yssel, J.H. Phillips, H. Spits, and L.L. Lanier (1993), "Functional Expression of B7/BB1 on Activated T Lymphocytes." *J. Exp. Med.* 177:845-850; Freeman, G.J., A.S. Freedman, J.M. Segil, G. Lee, J.F. Whitman, and L.M. Nadler (1989), "B7, A New Member of the Ig Superfamily with Unique Expression on Activated and Neoplastic B Cells." *The Journal of Immunology* 143:2714-2722; Hathcock, K.S., G. Laslo, H.B. Dickler, J. Bradshaw, P. Linsley, and R.J. Hodes (1993), "Identification of an Alternative CTLA-4 Ligand Costimulatory for T Cell Activation." *Science* 262:905-911; Hart, D.N.J., G.C. Starling, V.L. Calder, and N.S. Fernando (1993), "B7/BB-1 is a Leucocyte Differentiation Antigen on Human Dendritic Cells Induced by Activation." *Immunology* 79:616-620). It can be shown *in vitro* that the absence of these co-stimulatory signals leads to an aborted T cell activation pathway and the development of unresponsiveness to the specific antigen, or anergy. (See, e.g., Harding, F.A., J.G. McArthur, J.A. Gross, D.M. Raulet, and J.P. Allison (1992), "CD28 Mediated Signaling Co-stimulates Murine T Cells and Prevents Induction of Anergy in T Cell Clones." *Nature* 356:607-609; Gimmi, C.D., G.J. Freeman, J.G. Gribben, G. Gray, and L.M. Nadler (1993); "Human T-Cell Clonal Anergy is Induced by Antigen Presentation in the Absence of B7 Costimulation.", *Proc. Natl. Acad. Sci.* 90:6586-6590; Tan, P., C. Anasefti, J.A. Hansen, J. Melrose, M. Brunvand, J. Bradshaw, J.A. Ledbetter, and P.S. Linsley (1993), "Induction of Alloantigen-specific Hyporesponsiveness in Human T

Lymphocytes by Blocking Interaction of CD28 with Its Natural Ligand B7/BB1." *J. Exp. Med.* 177:165-173). Achievement of *in vivo* tolerance constitutes a mechanism for immunosuppression and a viable therapy for organ transplant rejection and for the treatment of autoimmune diseases. This has been achieved in experimental models following the administration of CTLA-4Ig (Lenschow, D.J., Y. Zeng, R.J. Thistlethwaite, A. Montag, W. Brady, M.G. Gibson, P.S. Linsley, and J.A. Bluestone (1992), "Long-Term Survival of Xenogeneic Pancreatic Islet Grafts Induced by CTLA-4Ig." *Science* 257:789-795).

The molecules B7.1 and B7.2 can bind to either CD28 or CTLA-4, although B7.1 binds to CD28 with a Kd of 200 Nm and to CTLA-4 with a 20-fold higher affinity (Linsley, P.S., E.A. Clark, and J.A. Ledbetter (1990), "T-Cell Antigen CD28 Mediates Adhesion with B Cells by Interacting with Activation Antigen B7/BB-1." *Proc. Natl. Acad. Sci.* 87:5031-5035; Linsley et al (1993), "The Role of the CD28 receptor during T cell responses to antigen," *Annu. Rev. Immunol.* 11:191-192; Linesley et al (1993), "CD28 Engagement by B7/BB-1 Induces Transient Down-Regulation of CD28 Synthesis and Prolonged Unresponsiveness to CD28 Signaling," *The Journal of Immunology* 150:3151-3169). B7.1 is expressed on activated B cells and interferon induced monocytes, but not resting B cells (Freeman, G.J., G.S. Gray, C.D. Gimmi, D.B. Lomarrd, L-J. Zhou, M. White, J.D. Fingerroth, J.G. Gribben, and LM. Nadler (1991). "Structure, Expression and T Cell Costimulatory Activity of the Murine Homologue of the Human B Lymphocyte

Activation Antigen B7," *J. Exp. Med.*, 174:625-631). B7.2, on the other hand, is constitutively expressed at very low levels on resting monocytes, dendritic cells and B cells, and its expression is enhanced on activated T cells, NK cells and B lymphocytes (Azuma, M. D. Ito, H. Yagita, K. Okumura, J.H. Phillips, L.L. Lanier, and C. Somoza 1993, "B70 Antigen is a Second Ligand for CTLA-4 and CD28," *Nature*, 366:76-79). Although B7.1 and B7.2 can be expressed on the same cell type, their expression on B cells occurs with different kinetics (Lenschow, D.J., G.H. Su, L.A. Zuckerman, N. Nabavi, C.L. Jellis, G.S. Gray, J. Miller, and J.A. Bluestone (1993), "Expression and Functional Significance of an Additional Ligand for CTLA-4," *Proc. Natl. Acad. Sci., USA*, 90:11054-11058; Boussiotis, V.A., G.J. Freeman, J.G. Gribben, J. Daley, G. Gray, and L.M. Nadler (1993), "Activated Human B Lymphocytes Express Three CTLA-4 Counter-receptors that Co-stimulate T-Cell Activation." *Proc. Natl. Acad. Sci., USA*, 90:11059-11063). Further analysis at the RNA level has demonstrated that B7.2 mRNA is constitutively expressed, whereas B7.1 MRNA is detected 4 hours after activation and initial low levels of B7.1 protein are not detectable until 24 hours after stimulation (Boussiotis, V.A., G.J. Freeman, J.G. Gribben, J. Daley, G. Gray, and L.M. Nadler (1993), "Activated Human B Lymphocytes Express Three CTLA-4 Counter-receptors that Co-stimulate T-Cell Activation," *Proc. Natl. Acad. Sci., USA*, 90:11059-11063). CTLA-4/CD28 counter receptors, therefore, may be expressed at various times after B Cell activation.

More recently, it has been suggested that the second T cell associated co-receptor CTLA-4 apparently functions as a negative modulator to override and prevent a runaway immune system (Krummel M, Allison J: "CD28 and CTLA-4 have opposing effects on the response of T cells to stimulation." *J. Exp. Med.* 182:459-466 (1995)). The CTLA-4 receptor plays a critical role in down regulating the immune response, as evidenced in CTLA-4 knockout mice. Knockout mice born without the ability to express the CTLA-4 gene die within 3-4 weeks of severe lymphoproliferative disorder (Tivol EA, Borriello G, Schweitzer AN, Lynch WP, Bluestone JA, Sharpe AH: "Loss of CTLA-4 leads to massive lymphoproliferation and fatal multiorgan tissue destruction, revealing a critical negative regulatory role of CTLA-4." *Immunity* 3:541-547 (1995)). CTLA-4 is thought to function through signaling mechanisms linked to induction of apoptosis (Gribben JG, Freeman GJ, Boussiotis VA, Rennert P, Jellis CL, Greenfield E, Barber M, Restivo Jr. VA, Ke X, Gray GS, Nadler LM: "CTLA-4 mediates antigen specific apoptosis of human T cells." *Proc. Natl. Acad. Sci. USA* 92:811-815 (1995)), triggered through as yet undefined ligand binding to specific sites on the receptor. It has been shown *in vitro* that the blocking of the B7.1/B7.2 dependent co-stimulatory signals in various ways leads to an aborted T cell activating pathway and the development of unresponsiveness to the specific antigen (Lederman S, Chess L, Yellin MJ: "Murine monoclonal antibody (5c8) recognizes a human glycoprotein on the surface of T-lymphocytes, compositions containing same." U.S. Patent No. 5,474,771 (December 12, 1995); Linsley PS, Ledbetter

JA, Damle NK, Brady W: "Chimeric CTLA4 receptor and methods for its use." U.S. Patent No. 5,434,131 (July 18, 1995); Harding, 1992; Gimmi CD, Freeman GJ, Bribben JG, Gray G, Nadler LM: "Human T-cell clonal anergy is induced by antigen presentation in the absence of B7 costimulation." *Proc. Natl. Acad. Sci. (USA)* 90:6586-6590 (1993);

5 Tan P, Anasetti C, Hansen JA, Melrose J, Brunvand M, Bradshaw J, Ledbetter JA, Linsley PS: "Induction of alloantigen-specific hyporesponsiveness in human T lymphocytes by blocking interaction of CD28 with its natural ligand B7/BB1." *J. Exp. Med.* 177:165-173 (1993)). Achievement of *in vivo* tolerance, anergy, or depleting of antigen-specific T cells would constitute a mechanism for immunosuppression and a

10 viable therapy for organ transplant rejection or plausible treatment for autoimmune diseases.

The differential temporal expression of B7.1 and B7.2 suggests that the interaction of these two molecules with CTLA-4 and/or CD28 deliver distinct but related signals to the T cell (LaSalle, J.M., P.J. Tolentino, G.J. Freeman, L.M. Nadler, and D.A. Hafler, (1992), "CD28 and T Cell Antigen Receptor Signal Transduction Coordinately Regulate Interleukin 2 Gene Expression In Response to Superantigen Stimulation," *J. Exp. Med.*, 176:177-186; Vandenberghe, P., G.J. Freeman, L.M. Nadler, M.C. Fletcher, M. Kamoun, L.A. Turka, J.A. Ledbetter, C.B. Thompson, and C.H. June (1992), "Antibody and B7/BB1-mediated Ligation of the CD28 Receptor Induces Tyrosine Phosphorylation in

15 Human T Cells," *The Journal of Experimental Medicine* 175:951-960)). The exact

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signaling functions of CTLA-4 and CD28 on the T cell are currently unknown (Janeway, C.A., Jr. and K. Bottomly, (1994), "Signals and Signs for Lymphocyte Responses," *Cell* 76:275-285). However, it is possible that one set of receptors could provide the initial stimulus for T cell activation and the second, a sustained signal to allow further elaboration of the pathway and clonal expansion to take place (Linsley, P.S., J.L. Greene, P. Tan, J. Bradshaw, J.A. Ledbetter, C. Anasetti, and N.K. Damle, (1992), "Coexpression and Functional Cooperation of CTLA-4 and CD28 on Activated T Lymphocytes," *J. Exp. Med.* 176:1595-1604). The current data supports the two-signal hypothesis proposed by Jenkins and Schwartz (Schwartz, R.H. (1990), "A Cell Culture Model for T Lymphocyte Clonal Anergy," *Science* 248:1349; Jenkins, M.K., (1992), "The Role of Cell Division in the Induction of Clonal Anergy," *Immunology Today* 13:69)) that both a TCR and co-stimulatory signal are necessary for T cell expansion, lymphokine secretion and the full development of effector function (Greenan, V. and G. Kroemer (1993), "Multiple Ways to Cellular Immune Tolerance," *Immunology Today* 14:573). The failure to deliver the second signal results in the inability of T cells to secrete IL-2 and renders the cell unresponsive to antigen.

Structurally, both B7.1 and B7.2 contain extracellular immunoglobulin superfamily V and C-like domains, a hydrophobic transmembrane region and a cytoplasmic tail (Freeman, G.J., J.G. Gribben, V.A. Boussiotis, J.W. Ng, V. Restivo, Jr., L.A. Lombard, G.S. Gray, and L.M. Nadler (1993), "Cloning of B7.2: A CTLA-4

Counter-receptor that Co-stimulates Human T Cell Proliferation," *Science* 262:909). Both B7.1 and B7.2 are heavily glycosylated. B7.1 is a 44-54kD glycoprotein comprised of a 223 amino acid extracellular domain, a 23 amino acid transmembrane domain, and a 61 amino acid cytoplasmic tail. B7.1 contains 3 potential protein kinase phosphorylation sites. (Azuma, M., H. Yssel, J.H. Phillips, H. Spits, and L.L. Lanier, (1993), "Functional Expression of B7/BB1 on Activated T Lymphocytes," *J. Exp. Med.* 177:845-850). B7.2 is a 306 amino acid membrane glycoprotein. It consists of a 220 amino acid extracellular region, a 23 amino acid hydrophobic transmembrane domain and a 60 amino acid cytoplasmic tail (Freeman, G.J., A.S. Freedman, J.M. Segil, G. Lee, J.F. Whitman, and L.M. Nadler (1989), "B7, A New Member of the Ig Superfamily with Unique Expression on Activated and Neoplastic B Cells," *The Journal of Immunology* 143:2714-2722). Although both B7.1 and B7.2 genes are localized in the same chromosomal region (Freeman, G.J., D.B. Lombard, C.D. Gimmi, S.A. Brod, L Lee, J.C. Laning, D.A. Hafler, M.E. Dorf, G.S. Gray, H. Reiser, C.H. June, C.B. Thompson, and L.M. Nadler (1992), "CTLA-4 and CD28 mRNA are Coexpressed in Most T Cells After Activation," *The Journal of Immunology* 149:3795-3801; Schwartz, R.H. (1992), "Costimulation of T Lymphocytes: The Role of CD28, CTLA-4, and B7/BB1" in Selvakumar, A., B.K. Mohanraj, R.L. Eddy, T.B. Shows, P.C. White, C. Perrin, and B. Dupont (1992), "Genomic Organization and Chromosomal Location of the Human Gene Encoding the B-Lymphocyte Activation Antigen B7," *Immunogenetics* 36:175-181),

these antigens do not share a high level of homology. The overall homology between B7.1 and B7.2 is 26% and between murine B7.1 and human B7.1 is 27% (Azuma, M., H. Yssel, J.H. Phillips, H. Spits, and L.L. Lanier (1993), "Functional Expression of B7/BB1 on Activated T Lymphocytes," *J. Exp. Med.* 177:845-850; Freeman, G.J., A.S. Freedman, J.M. Segil, G. Lee, J.F. Whitman, and LM. Nadler (1989), "B7, A New Member of the Ig Superfamily with Unique Expression on Activated and Neoplastic B Cells," *The Journal of Immunology* 143:2714-2722). Although alignment of human B7.1 human B7.2 and murine B7.1 sequences shows few stretches of lengthy homology, it is known that all three molecules bind to human CTLA-4 and CD28. Thus, there is most likely a common, or closely homologous region shared by the three molecules that may be either contiguous or conformational. This region may constitute the binding site of the B7.1 and B7.2 molecules to their counter-receptors. Antibodies raised against these epitopes could potentially inhibit the interaction of B7 with its counter-receptor on the T cell. Furthermore, antibodies that cross-reacted with this region on both B7.1 and B7.2 molecules would potentially have practical advantages over antibodies directed against B7.1 or B7.2 separately.

2. Blockade of the B7/CD28 Interaction

Blocking of the B7/CD28 interaction offers the possibility of inducing specific immunosuppression, with potential for generating long lasting antigen-specific therapeutic effects. Antibodies or agents that temporarily prevent this interaction may be

useful, specific and safe clinical immunosuppressive agents, with potential for generating long term antigen-specific therapeutic effects.

Antibodies to either B7.1 or B7.2 have been shown to block T cell activation, as measured by the inhibition of IL-2 production *in vitro* (DeBoer, M., P. Parren, J. Dove, F. Ossendorp, G. van der Horst, and J. Reeder (1992), "Functional Characterization of a Novel Anti-B7 Monoclonal Antibody," *Eur. Journal of Immunology* 22:3071-3075; Azuma, M., H. Yssel, J.H. Phillips, H. Spits, and L.L. Lanier (1993), "Functional Expression of B7/BB1 on Activated T Lymphocytes," *J. Exp. Med.* 177:845-850)). However, different antibodies have been shown to vary in their immunosuppressive potency, which may reflect either their affinity or epitope specificity. A possible explanation for this may reside in the ability of some antibodies to block only the binding of B7 to CD28, while promoting apoptosis or some other form of negative signaling through the CTLA-4 receptor in activated T cells. Some antibodies to B7.1 or B7.2 may, in fact, hinder the activity of CTLA-4 by cross-reacting with the CTLA-4 binding domain. CTLA-4Ig fusion protein and anti-CD28 Fabs were shown to have similar effects on the down regulation of IL-2 production.

In vivo administration of a soluble CTLA-4Ig fusion protein has been shown to suppress T cell dependent antibody responses in mice (Linsley, P.S., J.L. Greene, P. Tan, J. Bradshaw, J.A. Ledbetter, C. Anasetti, and N.K. Damle (1992), "Coexpression and Functional Cooperation of CTLA-4 and CD28 on Activated T Lymphocytes," *J. Exp.*

Med. 176:1595-1604; Lin, H., S.F. Builing, P.S. Linsley, R.O. Wei, C.D. Thompson, and L.A. Turka (1993), "Long-term Acceptance of Major Histocompatibility Complex Mismatched Cardiac Allografts Induced by CTLA-4-Ig Plus Donor Specific Transfusion," *J. Exp. Med.* 178:1801) and, furthermore, larger doses were also able to suppress responses to a second immunization, demonstrating the feasibility of this approach for the treatment of antibody mediated autoimmune disease. In addition, CTLA-4Ig was able to prevent pancreatic islet cell rejection in mice by directly inhibiting the interaction of T cells and B7.1/B7.2 antigen presenting cells (Lenschow, D.J., G.H. Su, L.A. Zuckerman, N. Nabavi, C.L. Jellis, G.S. Gray, J. Miller, and J.A. Bluestone (1993), "Expression and Functional Significance of an Additional Ligand for CTLA-4," *Proc. Natl. Acad. Sci., USA* 90:11054-11058). In this case, long term donor specific tolerance was achieved.

3. Recombinant Phage Display Technology for Antibody Selection

To date, no monoclonal antibodies which cross-react with both B7.1 and B7.2 have been reported. Furthermore, no monoclonal antibodies which are specific to B7.1 or B7.2 and which also recognize specific sites on the antigens which are restricted to co-activation receptor CD28 binding have been reported. Or alternatively, no monoclonal antibodies which are specific to B7.1 or B7.2 and which recognize specific sites on the antigens which are exclusive of CTLA-4 receptor binding have been reported. As discussed supra, such antibodies would potentially be highly desirable as immunosuppressants.

Phage display technology is beginning to replace traditional methods for isolating antibodies generated during the immune response, because a much greater percentage of the immune repertoire can be assessed than is possible using traditional methods. This is in part due to PEG fusion inefficiency, chromosomal instability, and the large amount of tissue culture and screening associated with heterohybridoma production. Phage display technology, by contrast, relies on molecular techniques for potentially capturing the entire repertoire of immunoglobulin genes associated with the response to a given antigen.

This technique is described by Barbas et al, *Proc. Natl. Acad. Sci., USA* 88:7978-7982 (1991). Essentially, immunoglobulin heavy chain genes are PCR amplified and cloned into a vector containing the gene encoding the minor coat protein of the

filamentous phage M13 in such a way that a heavy chain fusion protein is created. The heavy chain fusion protein is incorporated into the M13 phage particle together with the light chain genes as it assembles. Each recombinant phage contains, within its genome, the genes for a different antibody Fab molecule which it displays on its surface. Within these libraries, in excess of 10^6 different antibodies can be cloned and displayed. The phage library is panned on antigen coated microliter wells, non-specific phage are washed off, and antigen binding phage are eluted. The genome from the antigen-specific clones is isolated and the gene III is excised, so that antibody can be expressed in soluble Fab form for further characterization. Once a single Fab is selected as a potential therapeutic candidate, it may easily be converted to a whole antibody. A previously described expression system for converting Fab sequences to whole antibodies is IDEC's mammalian expression vector NEOSPLA. This vector contains either human gamma 1 or gamma 4 constant region genes. CHO cells are transfected with the NEOSPLA vectors and after amplification this vector system has been reported to provide very high expression levels (> 30 pg/cell/day) can be achieved.

4. Primatized Antibodies

Another highly efficient means for generating recombinant antibodies is disclosed by Newman (1992), *Biotechnology* 10, 1455-1460. More particularly, this technique results in the generation of primatized antibodies which contain monkey variable domains and human constant sequences. This reference is incorporated by reference in its entirety

herein. Moreover, this technique is also described in commonly assigned U.S. Serial No. 08/379,072, filed on January 25, 1995, now U.S. Patent No. 5,658,570, which is a continuation of U.S. Serial No. 07/912,292, filed July 10, 1992, which is a continuation-in-part of U.S. Serial No. 07/856,281, filed March 23, 1992, which is a continuation-in-part of U.S. Serial No. 07/735,064, filed July 25, 1991. U.S. Patent No. 5,658,570, and the parent applications thereof are incorporated by reference in their entirety herein.

This technique modifies antibodies such that they are not antigenically rejected upon administration in humans. This technique relies on immunization of cynomolgus monkeys with human antigens or receptors. This technique was developed to create high affinity monoclonal antibodies directed to human cell surface antigens.

Identification of macaque antibodies to human B7.1 and B7.2 by screening of phage display libraries or monkey heterohybridomas obtained using B lymphocytes from B7.1 and/or B7.2 immunized monkeys is also described in commonly assigned U.S. Application No. 08/487,550, filed June 7, 1995, incorporated by reference in its entirety herein. More specifically, 08/487,550 provides four monoclonal antibodies 7B6, 16C10, 7C10 and 20C9 which inhibit the B7:CD28 pathway and thereby function as effective immunosuppressants.

Antibodies generated in the manner described by these co-assigned applications have previously been reported to display human effector function, have reduced immunogenicity, and long serum half-life. The technology relies on the fact that despite

the fact that cynomolgus monkeys are phylogenetically similar to humans, they still recognize many human proteins as foreign and therefore mount an immune response. Moreover, because the cynomolgus monkeys are phylogenetically close to humans, the antibodies generated in these monkeys have been discovered to have a high degree of amino acid homology to those produced in humans. Indeed, after sequencing macaque immunoglobulin light and heavy chain variable region genes, it was found that the sequence of each gene family was 85-98% homologous to its human counterpart (Newman et al, (1992), *Id.*). The first antibody generated in this way, an anti-CD4 antibody, was 91-92% homologous to the consensus sequence of human immunoglobulin framework regions. Newman et al, *Biotechnology* 10:1458-1460 (1992).

Monoclonal antibodies specific to the human B7 antigen have been previously described in the literature. For example, Weyl et al, *Hum. Immunol.* 31(4), 271-276 (1991) describe epitope mapping of human monoclonal antibodies against HLA-B-27 using natural and mutated antigenic variants. Also, Toubert et al, *Clin. Exp. Immunol.* 82(1), 16-20 (1990) describe epitope mapping of an HLA-B27 monoclonal antibody that also reacts with a 35-KD bacterial outer membrane protein. Also, Valle et al, *Immunol.* 69(4), 531-535 (1990) describe a monoclonal antibody of the IgG1 subclass which recognizes the B7 antigen expressed in activated B cells and HTLV-1-transformed T cells. Further, Toubert et al, *J. Immunol.* 141(7), 2503-9 (1988) describe epitope mapping

of HLA-B27 and HLA-B7 antigens using intradomain recombinants constructed by making hybrid genes between these two alleles in *E. coli*.

High expression of B7 antigen has been correlated to autoimmune diseases by some researchers. For example, Ionesco-Tirgoviste et al, *Med. Interre* 24(1), 11-17 (1986) report increased B7 antigen expression in type 1 insulin-dependent diabetes. Also, the involvement of B7 antigen expression on dermal dendritic cells obtained from psoriasis patients has been reported. (Nestle et al, *J. Clin. Invest.* 94(1), 202-209 (1994)).

Further, the inhibition of anti-HLA-B7 alloreactive CTL using affinity-purified soluble HLA-B7 has been reported in the literature. (Zavazava et al, *Transplantation* 51(4), 838-42 (1991)). Further, the use of B7 receptor soluble ligand, CTLA-4-Ig to block B7 activity (See, e.g., Lenschow et al, *Science* 257, 789, 7955 (1992)) in animal models and a B7.1-Ig fusion protein capable of inhibiting B7 has been reported.

Evidence is provided in this disclosure for the identification of monoclonal antibodies which recognize specific sites on the B7.1 antigen which are restricted to CD28 receptor binding. Furthermore, evidence is presented herein for the identification of antibodies which recognize sites on the B7.1 antigen which are exclusive of CTLA-4 receptor binding. Thus, evidence is presented herein to support the existence of unique antigen binding sites on the human B7.1 (CD80) co-stimulatory antigen. The sites claimed are identified by anti-B7.1 PRIMATIZED® antibodies and evidence is presented

which confirms binding to a site of interaction on the B7.1 antigen which is restricted to binding with the co-activation receptor CD28.

SUMMARY AND OBJECTS OF THE INVENTION

5 An object of the invention is to identify novel antibodies which are specific to human B7.1 antigen. More specifically, it is an object of the invention to identify antibodies which are specific to human B7.1 antigen and which are also capable of inhibiting the binding of B7.1 to a CD28 receptor. It is also an object of this invention to identify antibodies which are specific to human B7.1 antigen and which are not capable of inhibiting the binding of B7.1 to a CTLA-4 receptor. Thus, an object of this invention is to identify antibodies which recognize specific sites on the B7.1 antigen, wherein the recognized sites are restricted to CD28 receptor binding and which are exclusive of CTLA-4 receptor binding.

10 It is a further object of the invention to identify antibodies which are specific to human B7.1 antigen and which fail to recognize human B7.2 antigen.

15 It is another object of the invention to identify monoclonal antibodies and primatized forms thereof which recognize specific sites on the human B7.1 antigen and which inhibit IL-2 production and T cell proliferation and which function as effective immunosuppressants. More specifically, it is an object of this invention to identify antibodies which are specific to B7.1 and which are capable of inhibiting IL-2 production.

20 It is another object of the invention to provide monoclonal antibodies and

primatized forms thereof which inhibit antigen driven responses in donor spleen cell cultures, e.g., antigen specific IgG responses, IL-2 production and cell proliferation.

It is another specific object of the invention to identify particular monoclonal antibodies specific to human B7.1 antigen and primatized forms thereof having advantageous properties, i.e., affinity, immunosuppressive activity, which are useful as therapeutics. More specifically, these antibodies and primatized forms thereof are to be used, e.g., as immunosuppressants, i.e., to block antigen driven immune responses, to treat autoimmune diseases such as psoriasis, rheumatoid arthritis, systemic erythematosus (SLE), type 1 diabetes mellitus, idiopathic thrombocytopenia purpura (ITP), allergy, inflammatory bile disease, and to prevent organ rejection.

It is another object of the invention to provide pharmaceutical compositions containing one or more monoclonal antibodies specific to human B7.1 antigen or primatized forms thereof, and a pharmaceutically acceptable carrier or excipient. These compositions will be used, e.g., as immunosuppressants to treat autoimmune diseases, e.g., idiopathic thrombocytopenia purpura (ITP) and systemic lupus erythematosus (SLE), to block antigen driven immune responses, and to prevent organ rejection in transplant recipients.

It is another object of the invention to provide novel methods of therapy by administration of therapeutically effective amounts of one or more or primatized monoclonal antibodies which specifically bind to human B7.1 antigen. Such therapeutic

methods are useful for treatment of diseases treatable by inhibition of the B7:CD28 pathway, e.g., autoimmune diseases such as idiopathic thrombocytopenia purpura (ITP), systemic lupus erythematosus (SLE), type 1 diabetes mellitus, psoriasis, rheumatoid arthritis, multiple sclerosis, aplastic anemia, as well as for preventing rejection in transplantation subjects.

It is still another object of the invention to provide transfectants, e.g., CHO cells, which express at least the variable heavy and light domains of monoclonal antibodies specific to the human B7.1 antigen.

Definitions

The following terms are defined so that the invention may be more clearly understood.

Depleting antibody - an antibody which kills activated B cells or other antigen presenting cells.

Non-depleting antibody - an antibody which blocks the co-stimulatory action of B7 and T cell activating ligands CD28 and CTLA-4. Thus, it anergizes but does not eliminate the antigen presenting cell.

Primatized antibody - a recombinant antibody which has been engineered to contain the variable heavy and light domains of a monkey antibody, in particular, a cynomolgus monkey antibody, and which contains human constant domain sequences, preferably the human immunoglobulin gamma 1 or gamma 4 constant domain (or PE variant). The

preparation of such antibodies is described in Newman et al, (1992), "Primatization of Recombinant Antibodies for Immunotherapy of Human Diseases: A Macaque/Human Chimeric Antibody Against Human CDH, *Biotechnology* 10:1458-1460; also in commonly assigned U.S. Serial No. 08/379,072, now U.S. Patent No. 5,658,570, both of which are incorporated by reference in their entirety herein. These antibodies have been reported to exhibit a high degree of homology to human antibodies, i.e., 85-98%, display human effector functions, have reduced immunogenicity, and may exhibit high affinity to human antigens.

B7 antigens - B7 antigens in this application include, e.g., human B7, B7.1 and B7.2 antigens. These antigens bind to CD28 and/or CTLA-4. These antigens have a co-stimulatory role in T cell activation. Also, these B7 antigens all contain extracellular immunoglobulin superfamily V and C-like domains, a hydrophobic transmembrane region and a cytoplasmic tail (*See*, Freeman et al, *Science* 262:909, (1993)), and are heavily glycosylated.

Anti-B7 antibodies - Antibodies, preferably monkey monoclonal antibodies or primatized forms thereof, which specifically bind human B7 antigens, e.g., human B7.1 and/or B7.2 antigen with a sufficient affinity to block the B7:CD28 interaction, but h do not block the B7/CTLA-4 receptor interaction and thereby induce immunosuppression.

BRIEF DESCRIPTION OF THE FIGURES

Figure 1 depicts the pMS vector used to screen recombinant immunoglobulin libraries produced against B7 displayed on the surface of filamentous phage which contains primers based on macaque immunoglobulin sequences.

5 Figure 2 depicts the NEOSPLA expression vector used to express the subject primatized antibodies specific to human B7.1 antigen.

Figure 3a depicts the amino acid and nucleic acid sequence of a primatized form of the light chain of 7C10.

10 Figure 3b depicts the amino acid and nucleic acid sequence of a primatized form of the heavy chain of 7C10.

Figure 4a depicts the amino acid and nucleic acid sequence of a primatized form of the light chain of 7B6.

Figure 4b depicts the amino acid and nucleic acid sequence of a primatized form of the heavy chain of 7B6.

15 Figure 5a depicts the amino acid and nucleic acid sequence of a primatized light chain 16C10.

Figure 5b depicts the amino acid and nucleic acid sequence of a primatized heavy chain 16C10.

20 Figure 6 depicts the inability of P16C10 to block CTLA-4Ig-Biotin binding to B7.1 transfected CHO cells.

Figure 7 depicts the inability of CTLA-4Ig to block P16C10-Biotin binding to B7.1 transfected CHO cells.

Figure 8 depicts that BB-1 completely blocks binding of CTLA-4Ig-Biotin to B7.1 transfected CHO cells and further depicts the inability of BB-1 to significantly affect P16C10-Biotin binding to B7.1 transfected CHO cells.

Figure 9 depicts that CTLA-4Ig-Biotin is effectively blocked by all B7.1 inhibitors except P16C10.

Figure 10 depicts the ability of P16C10 to block binding of the CD28/B7-1Ig interaction. Data shown are averages of values obtained from four separate experiments.

Figure 11 depicts production of IL-2 in cultures of purified normal human CD4+ lymphocytes when stimulated with sub-optimal amounts of immobilized anti-CD3 antibody and B7-1 (CD80) on latex microbeads. L307.4 is a commercially available murine antibody (B/D Pharmingen) that binds specifically to human CD80 and neutralizes CD28:CD80 functional interactions. CTLA-4Ig is a soluble receptor fusion protein that specifically blocks CD80 and CD86 binding to CD28 receptors on T cells. IDEC-114 is a PRIMATIZED monoclonal antibody that specifically binds to both soluble and membrane forms of the CD80 antigen but does not recognize CTLA-4 or B7-2 antigens. The ratio of anti-CD3 to B7Ig used in the cultures to stimulate T cells was 1:10 (w/w).

Figure 12 depicts uptake of H3-Thymidine in cultures of purified normal human CD4+ lymphocytes when stimulated with sub-optimal amounts of immobilized anti-CD3 antibody and B7-1 (CD80) on latex microbeads. L307.4 is a commercially available murine antibody (B/D Pharmingen) that binds specifically to human CD80 and neutralizes CD28:CD80 functional interactions. CTLA-4Ig is a soluble receptor fusion protein that specifically blocks CD80 and CD86 binding to CD28 receptors on T cells. IDEC-114 is a PRIMATIZED monoclonal antibody that specifically binds to both soluble and membrane forms of the CD80 antigen but does not recognize CTLA-4 or B7-2 antigens.

Figure 13 depicts production of TH2 cytokine IL-10 in cultures of purified normal human CD4+ lymphocytes when stimulated with sub-optimal amounts of immobilized anti-CD3 antibody and B7-1 (CD80) on latex microbeads. Inhibition of IL-10 production by L307.4 anti-CD80 and CTLA-4Ig fusion protein was compared at 0.1, 1, and 10 μ g/mL.

Figure 14 depicts inhibition of IL-2 cytokine production by CTLA-4Ig and IDEC-114 in cultures of purified human CD4+ T cells. T cells were co-stimulated with anti-CD3 and B7Ig coated latex microbeads with an anti-CD3/B7 ratio (w/w) of 8:1. IL-2 was determined by growth and uptake of Thymidine by the IL-2 dependent cell line CTLL-2.

DETAILED DESCRIPTION OF THE INVENTION

As described above, the present invention relates to the identification of monoclonal antibodies or primatized forms thereof which are specific to human B7.1

antigen and which are capable of inhibiting the binding of B7.1 to a CD28 receptor and which are not capable of inhibiting the binding of B7.1 to a CTLA-4 receptor. Blocking of the primary activation site between CD28 and B7.1 (CD80) with the identified antibodies while allowing the combined antagonistic effect on positive co-stimulation with an agnostic effect on negative signaling will be a useful therapeutic approach for intervening in relapsed forms of autoimmune disease. The functional activity of the identified antibodies is defined by blocking the production of the T cell stimulatory cytokine IL-2. Identified antibodies have demonstrated the ability to block the production of IL-2 in excess of 50%, in spite of the existence of a second actuating ligand B7.2, suggesting an alternate mechanism of action exists which is not typical of the observed effects of other anti-B7.1 antibodies defined in the literature.

Manufacture of novel monkey monoclonal antibodies which specifically bind human B7.1 and/or human B7.2 antigen, as well as primatized antibodies derived therefrom is described in co-pending U.S. Application Serial No. 08/487,550, and as set forth herein. These antibodies possess high affinity to human B7.1 and/or B7.2 and therefore may be used as immunosuppressants which inhibit the B7:CD86 pathway.

Preparation of monkey monoclonal antibodies will preferably be effected by screening of phage display libraries or by preparation of monkey heterohybridomas using B lymphocytes obtained from B7 (e.g., human B7.1 and/or B7.2) immunized monkeys.

As noted, the first method for generating anti-B7 antibodies involves recombinant phage display technology. This technique is generally described *supra*.

Essentially, this will comprise synthesis of recombinant immunoglobulin libraries against B7 antigen displayed on the surface of filamentous phage and selection of phage which secrete antibodies having high affinity to B7.1 and/or B7.2 antigen. As noted *supra*, preferably antibodies will be selected which bind to both human B7.1 and B7.2. To effect such methodology, the present inventors have created a unique library for monkey libraries which reduces the possibility of recombination and improves stability. This vector, PMS, is described in detail *infra*, and is shown in Figure 1.

Essentially, to adopt phage display for use with macaque libraries, this vector contains specific primers for PCR amplifying monkey immunoglobulin genes. These primers are based on macaque sequences obtained while developing the primate technology and databases containing human sequences.

Suitable primers are disclosed in commonly assigned U.S. Patent No. 5,658,570.

The second method involves the immunization of monkeys, i.e., macaques, against human B7 antigen, preferably against human B7.1 and B7.2 antigen. The inherent advantage of macaques for generation of monoclonal antibodies is discussed *supra*. In particular, such monkeys, i.e., cynomolgus monkeys, may be immunized against human antigens or receptors. Moreover, the resultant antibodies may be used to make primate antibodies according to the methodology of Newman et al, *Biotechnology* 10, 1455-1460

(1992), and Newman et al, commonly assigned U.S. Serial No. U.S. Patent No. 5,658,570, which are incorporated by reference in their entirety.

5 The significant advantage of antibodies obtained from cynomolgus monkeys is that these monkeys recognize many human proteins as foreign and thereby provide for the formation of antibodies, some with high affinity to desired human antigens, e.g., human surface proteins and cell receptors. Moreover, because they are phylogenetically close to humans, the resultant antibodies exhibit a high degree of amino acid homology to those produced in humans. As noted above, after sequencing macaque immunoglobulin light and heavy variable region genes, it was found that the sequence of each gene family was 85-88% homologous to its human counterpart (Newman et al, (1992), *Id.*).

10 Essentially, cynomolgus macaque monkeys are administered human B7 antigen, e.g., human B7.1 and/or human B7.2 antigen, B cells are isolated therefrom, e.g., lymph node biopsies are taken from the animals, and B lymphocytes are then fused with KH6/B5 (mouse x human) heteromyeloma cells using polyethylene glycol (PEG). 15 Heterohybridomas secreting antibodies which bind human B7 antigen, e.g., human B7.1 and/or human B7.2 antigen, are then identified.

Antibodies which bind to both B7.1 and B7.2 are desirable because such antibodies potentially may be used to inhibit the interaction of B7.1 and B7.2, as well as B7 with their counter-receptors, i.e., human CTLA-4 and CD28. Antibodies against these

epitopes may inhibit the interaction of both human B7.1 and human B7.2 with their counter receptors on the T cell. This may potentially provide synergistic effects.

However, antibodies which bind to only one of human B7 antigen, B7.1 antigen or B7.2 antigen, are also highly desirable because of the co-involvement of these molecules in T cell activation, clonal expansion lymphokine (IL-2) secretion, and responsiveness to antigen. Given that both human B7.1 and B7.2 bind to human CTLA-4 and CD28, it is probable that there is at least one common or homologous region (perhaps a shared conformational epitope or epitopes) to which macaque antibodies may potentially be raised.

The disclosed invention involves the use of an animal which is primed to produce a particular antibody. Animals which are useful for such a process include, but are not limited to, the following: mice, rats, guinea pigs, hamsters, monkeys, pigs, goats and rabbits.

A preferred means of generating human antibodies using SCID mice is disclosed in commonly-owned, co-pending U.S. Patent application Serial No. 08/488,376.

The present inventors elected to immunize macaques against human B7.1 antigen using recombinant soluble B7.1 antigen produced in CHO cells and purified by affinity chromatography using a L307.4-sepharose affinity column. However, the particular source of human B7 antigen, human B7.1 antigen or human B7.2 antigen is not critical,

provided that it is of sufficient purity to result in a specific antibody response to the particular administered B7 antigen and potentially to other B7 antigens.

The human B7 antigen, human B7.1 antigen (also called CD80) and human B7.2 antigen (also called CD86) genes have been cloned, and sequenced, and therefore may readily be manufactured by recombinant methods.

Preferably, the administered human B7 antigen, human B7.1 antigen and/or human B7.2 antigen will be administered in soluble form, e.g., by expression of a B7, B7.1 or B7.2 gene which has its transmembrane and cytoplasmic domains removed, thereby leaving only the extracellular portion, i.e., the extracellular superfamily V and C-like domains. (See, e.g., Grumet et al, *Hum. Immunol.* 40(3), p. 228-234 (1994), which teaches expression of a soluble form of human B7, which is incorporated by reference in its entirety herein)).

The macaques will be immunized with the B7, B7.1 and/or B7.2 antigen, preferably a soluble form thereof, under conditions which result in the production of antibodies specific thereto. Preferably, the soluble human B7, B7.1 or B7.2 antigen will be administered in combination with an adjuvant, e.g., Complete Freund's Adjuvant (CFA), Alum, Saponin, or other known adjuvants, as well as combinations thereof. In general, this will require repeated immunization, e.g., by repeated injection, over several months. For example, administration of soluble B7.1 antigen was effected in adjuvant,

with booster immunizations, over a 3 to 4 month period, with resultant production of serum containing antibodies which bound human B7.1 antigen.

After immunization B cells are collected, e.g., by lymph node biopsies taken from the immunized animals and B lymphocytes fused with KH6/B5 (mouse x human) heteromyeloma cells using polyethylene glycol. Methods for preparation of such heteromyelomas are known and may be found in U.S. Patent No. 5,658,570, by Newman et al.

Heterohybridomas which secrete antibodies which bind human B7, B7.1 and/or B7.2 are then identified. This may be effected by known techniques. For example, this may be determined by ELISA or radioimmunoassay using enzyme or radionucleotide labelled human B7, B7.1 and/or B7.2 antigen.

Cell lines which secrete antibodies having the desired specificity to human B7, B7.1 and/or B7.2 antigen are then subcloned to monoclonality.

In the present invention, the inventors screened purified antibodies for their ability to bind to soluble B7.1 antigen coated plates in an ELISA assay, antigen positive B cells, and CHO transfectomas which express human B7.1 antigen on their cell surface. In addition, the antibodies were screened for their ability to block B cell/T cell interactions as measured by IL-2 production and tritiated thymidine uptake in a mixed lymphocyte reaction (MLR), with B7 binding being detected using ¹²⁵I-radiolabeled soluble B7.1 (SB7.1).

Also, affinity purified antibodies from macaques were tested for their reactivity against CHO transfectants which expressed B7.1/Ig fusion proteins, and against CHO cells which produced human B7.2 antigen. These results indicated that the B7.1 immune sera bound to the B7.2 transfectomas. Binding of antibodies to B7.2 antigen may be confirmed using soluble B7.2-Ig reagents. As discussed in the examples, this may be effected by producing and purifying B7.2-Ig from CHO transfectomas in sufficient quantities to prepare a B7.2-Ig-sepharose affinity column. Those antibodies which cross-react with B7.2 will bind the B7.2-Ig-sepharose column.

Cell lines which express antibodies which specifically bind to human B7 antigen, B7.1 antigen and/or B7.2 antigen are then used to clone variable domain sequences for the manufacture of primatized antibodies essentially as described in Newman et al (1992), *Id.* and Newman et al, U.S. Serial No. 379,072, filed January 25, 1995, both of which are incorporated by reference herein. Essentially, this entails extraction of RNA therefrom, conversion to cDNA, and amplification thereof by PCR using Ig specific primers. Suitable primers are described in Newman et al, 1992, *Id.* and in U.S. Serial No. 379,072. (See, in particular, Figure 1 of U.S. Serial No. 379,072).

The cloned monkey variable genes are then inserted into an expression vector which contains human heavy and light chain constant region genes. Preferably, this is effected using a proprietary expression vector of IDEC, Inc., referred to as NEOSPLA. This vector is shown in Figure 2 and contains the cytomegalovirus promoter/enhancer,

the mouse beta globin major promoter, the SV40 origin of replication, the bovine growth hormone polyadenylation sequence, neomycin phosphotransferase exon 1 and exon 2, human immunoglobulin kappa or lambda constant region, the dihydrofolate reductase gene, the human immunoglobulin gamma 1 or gamma 4 PE constant region and leader sequence. This vector has been found to result in very high level expression of primatized antibodies upon incorporation of monkey variable region genes, transfection in CHO cells, followed by selection in G418 containing medium and methotrexate amplification.

For example, this expression system has been previously disclosed to result in primatized antibodies having high avidity ($K_d \leq 10^{-10}$ M) against CD4 and other human cell surface receptors. Moreover, the antibodies have been found to exhibit the same affinity, specificity and functional activity as the original monkey antibody. This vector system is substantially disclosed in commonly assigned U.S. Patent No. 5,658,570, incorporated by reference herein, as well as U.S. Serial No. 08/149,099, now U.S. Patent No. 5,736,137, also incorporated by reference in its entirety herein. This system provides for high expression levels, i.e., > 30 pg/cell/day.

As discussed *infra*, the subject inventors have selected four lead candidate monkey monoclonal antibodies which specifically bind the B7.1 antigen. These monkey monoclonal antibodies are referred to herein as 7B6, 16C10, 7C10 and 20C9.

As discussed in greater detail *infra*, these antibodies were evaluated for their ability to block B cell/T cell interactions as measured by IL-2 production and tritiated thymidine uptake in a mixed lymphocyte reaction for T cell binding experiments for T cell binding, human buffy coat peripheral blood lymphocytes were cultured for 3-6 days in the presence of PHA stimulator. B7 binding was radioassayed using ¹²⁵I-radiolabeled soluble B7.1. The observed results indicate that all of these antibodies bind B7.1 antigen with high affinity and effectively block B cell/T cell interactions as evidenced by reduced IL-2 production and reduced proliferation of mixed lymphocyte cultures.

The properties of these particular monkey monoclonal antibodies are summarized below:

1. Scatchard analysis showed that the apparent affinity constants (Kd) for the monkey antibodies binding to B7-Ig coated plates were approximated to be:

a:	7C10:	6.2 x 10 ⁻⁹ M
b:	16C10:	8.1 x 10 ⁻⁹ M
c:	7B6:	10.7 x 10 ⁻⁹ M
d:	20C9:	16.8 x 10 ⁻⁹ M

2. The antibodies were tested *in vitro* in a mixed lymphocyte reaction assay (MLR). The MLR showed that all 4 anti-B7.1 antibodies inhibit IL-2 production to different extents as shown by the following Ic₅₀ values:

a:	7B6:	5.0 µg/M
b:	16C10:	<0.1 µg/M
c:	20C9:	2.0 µg/M

d: 7C10: 5.0 µg/M

3. The monkey anti-B7.1 antibodies were tested for their ability to bind B7 on human peripheral blood lymphocytes (PBL). FACS analysis showed that all 4 monkey antibodies tested positive.
4. Monkey antibodies 16C10, 7B6, 7C10 and 20C9 were tested for C1q binding by FACS analysis. Results showed 7C10 monkey Ig had strong human C1q binding after incubating with B7.1 CHO-transfected cells. 16C10 was positive, while 20C9 and 7B6 monkey antibodies were negative.
5. To select an animal model for path-tox studies, the monkey antibodies were tested with animal blood from different species. It was determined that the monkey anti-B7.1 antibodies cross-reacted with human, chimpanzee.

Based on these properties, it would appear that three monkey monoclonal antibodies possess the most advantageous properties, 16C10, 7C10 and 20C9, with 16C10 and 7C10 being somewhat better than 20C9.

Using the techniques described *supra*, and in commonly assigned U.S. Patent No. 5,658,570, the present inventors have cloned the variable domains of 7C10, 7B6 and 16C10, and provide the amino acid and nucleic acid sequences of primatized forms of the 7C10 light chain, 7C10 heavy chain, 7B6 light chain, 7B6 heavy chain, 16C10 light chain and 16C10 heavy chain. These amino acid and nucleic acid sequences may be found in

Figures 3a and 3b, 4a and 4b, and 5a and 5b. The DNA and amino acid sequence for the human gamma 1, gamma 4 constant domain may be found in U.S. Patent No. 5,658,570.

As discussed *supra*, these primatized antibodies are preferably expressed using the NEOSPLA expression vector shown in Figure 2 which is substantially described in commonly assigned U.S. Patent No. 5,658,570, and U.S. Patent No. 5,736,137, incorporated by reference herein in its entirety.

As previously noted, the subject primatized antibodies will preferably contain either the human immunoglobulin gamma 1 or gamma 4 constant region, with gamma 4 preferably mutated at two positions to create gamma 4 PE. The gamma 4 PE mutant contains two mutations, a glutamic acid in the CH2 region introduced to eliminate residual FCR binding, and a proline substitution in the hinge region, intended to enhance the stability of the heavy chain disulfide bond interaction. (See, Alegre et al, *J. Immunol.* 148, 3461-3468 (1992); and Angel et al, *Mol. Immunol.* 30, 105-158 (1993), both of which are incorporated by reference herein).

Whether the subject primatized antibodies contain the gamma 1, gamma 4 or gamma 4 PE constant region largely depends on the particular disease target. Preferably, depleting and non-depleting primatized IgG1 and IgG4 antibodies are created and tested against specific disease targets.

Given the described binding and functional properties of the subject monkey monoclonal antibodies, these anti-B7.1 monoclonal antibodies and primatized forms

thereof should be well suited as therapeutic agents for blocking the B7:CD28 interaction thereby providing for immunosuppression. In particular, given their high affinity to B7.1 antigen and ability to block B cell/T cell interactions as measured by IL-2 production and tritiated thymidine uptake in mixed lymphocyte culture as well as their ability to effectively inhibit antigen driven responses in donor spleen cell cultures as shown by reduced antigen specific IgG responses, IL-2 production and cell proliferation, these monkey monoclonal antibodies and primatized forms thereof should function as effective immunosuppressants which modulate the B7:CD28 pathway. This is significant for the treatment of many diseases wherein immunosuppression is therapeutically desirable, e.g., autoimmune diseases, to inhibit undesirable antigen specific IgG responses, and also for prevention of organ rejection and graft-versus-host disease. Essentially, the subject antibodies will be useful in treating any disease wherein suppression of the B7:CD28 pathway is therapeutically desirable.

Key therapeutic indications for the subject anti-B7.1 antibodies include, by way of example, autoimmune diseases such as idiopathic thrombocytopenia purpura (ITP), systemic lupus erythematosus (SLE), type 1 diabetes mellitus, multiple sclerosis, aplastic anemia, psoriasis, allergy, inflammatory bile disease and rheumatoid arthritis.

Another significant therapeutic indication of the subject anti-B7.1 antibodies is for prevention of graft-versus-host-disease (GVHD) during organ transplant and bone marrow transplant (BMT). The subject antibodies may be used to induce host tolerance

to donor-specific alloantigens and thereby facilitate engraftment and reduce the incidence of graft rejection. It has been shown in a murine model of allogeneic cardiac transplantation that intravenous administration of CTLA4-Ig can result in immunosuppression or even induction of tolerance to alloantigen. (Lin et al, *J. Exp. Med.* 178:1801, 1993; Torka et al, *Proc. Natl. Acad. Sci., USA* 89:11102, 1992). It is expected that the subject primatized anti-B7.1 antibodies will exhibit similar or greater activity.

Antibodies produced in the manner described above, or by equivalent techniques, can be purified by a combination of affinity and size exclusion chromatography for characterization in functional biological assays. These assays include determination of specificity and binding affinity as well as effector function associated with the expressed isotype, e.g., ADCC, or complement fixation. Such antibodies may be used as passive or active therapeutic agents against a number of human diseases, including B cell lymphoma, infectious diseases including viral diseases such as HIV/AIDS, autoimmune and inflammatory diseases, and transplantation. The antibodies can be used either in their native form, or as part of an antibody/chelate, antibody/drug or antibody/toxin complex. Additionally, whole antibodies or antibody fragments (Fab₂, Fab, Fv) may be used as imaging reagents or as potential vaccines or immunogens in active immunotherapy for the generation of anti-idiotypic responses.

The amount of antibody useful to produce a therapeutic effect can be determined by standard techniques well known to those of ordinary skill in the art. The antibodies

will generally be provided by standard technique within a pharmaceutically acceptable buffer, and may be administered by any desired route. Because of the efficacy of the presently claimed antibodies and their tolerance by humans it is possible to administer these antibodies repetitively in order to combat various diseases or disease states within a human.

The anti-B7.1 antibodies (or fragments thereof) of this invention are useful for inducing immunosuppression, i.e., inducing a suppression of a human's or animal's immune system. This invention therefore relates to a method of prophylactically or therapeutically inducing immunosuppression in a human or other animal in need thereof by administering an effective, non-toxic amount of such an antibody of this invention to such human or other animal.

The ability of the compounds of this invention to induce immunosuppression has been demonstrated in standard tests used for this purpose, for example, a mixed lymphocyte reaction test or a test measuring inhibition of T-cell proliferation measured by thymidine uptake.

For example, *in vitro* assays were conducted that measured cell growth and activating cytokines produced in response to co-stimulatory signals that activate CD4⁺ T cells. The production and secretion of these cytokines occurs naturally in T cells under conditions where a primary and secondary signal is generated through interactions between T cells and antigen presenting cells. Normally a primary signal is initiated

through interaction of a antigen specific T cell receptor and MHC Class II molecules bearing the specific antigen on antigen presenting cells. A secondary or co-stimulatory signal is required to obtain maximal activation of T cells. Several T cell co-stimulatory receptors have been identified that drive the production of various cytokines, and up-regulate other cell surface receptors that function in growth and differentiation of T cells and hematopoietic accessory cells. Some of the known signaling T cell co-stimulatory receptors are CD28, CD11, CD54 and CD40L. Sustained adhesion and prolonged interactions through these cell surface molecules result in secretion of IL-2 and various secondary inflammatory cytokines that control numerous immuno-regulatory functions. The study of T cell interactions can be complex due to the presence of numerous accessory cell types capable of mediating redundant or interdependent co-stimulatory effects.

The CD28/B7 receptor ligand interaction is considered to be the key secondary response element between antigen presenting cells and CD4+ helper T cells in the immune response cascade. After a primary signal is generated between antigen specific T cell receptors and antigen/MHC class II complexes, two types of B7 molecules, B7-1 (CD80) and B7-2, (CD86) are up-regulated and establish a membrane signaling event through binding to CD28 receptor. These signals drive the gene expression of various cytokines beginning with the production of IL-2. The detection of secreted IL-2, cell proliferation and various cell surface activation markers including the receptor for IL-2

are clear indicators that co-stimulation has occurred and cells are beginning to divide and differentiate to maturity. T cells may be influenced or driven down different maturation pathways depending on many complex internal and external factors through mechanisms that are poorly understood. The CD28/B7 interaction was first identified as an adhesion event when a B7 specific antibody was identified that blocked adhesion between B and T cell types. CD28 is known to affect *in vivo* immune responses by functioning both as a cell adhesion molecule linking B and T lymphocytes and as the surface component of a novel signal transduction pathway (June et al. 1990, *Immunology Today*, 11: 211-216). As a result, several monoclonal antibodies that recognize either CD28 or B7 are capable of blocking both adhesion and signaling events. Blocking of either event would lead directly or indirectly to reduced signaling through the CD28 receptor and would result in reduced IL-2 production, proliferation and the appearance of secondary cytokines.

More specifically, the present inventors have isolated certain novel antibodies, the activity of which apparently does not involve directly blocking of signal transduction as demonstrated through the use of CTLA-4Ig, a soluble receptor fusion protein that co-recognizes both B7 receptors. Evidence is provided herein that a primatized antibody according to the invention, referred to as IDEC- 114 blocks adhesion of antigen presenting cells to T cells thereby blocking an upstream event prior to signaling that under certain conditions, possibly related to B7 receptor density, is capable of influencing T cell activation. Evidence is provided through use of an *in vitro* assay that establishes

distinct differences between the mechanism of action of IDEC- 114 and other anti-CD80 antibodies as well as CTLA-4Ig. The *in vitro* assay employed in these experiments was designed to reduce the number of complex interactions provided by accessory cells, by using a purified CD4+ T cell population and replacing accessory cells with a non-cellular co-stimulatory system. This cell activating system obviates the need for antigen presenting cells by using latex microspheres containing immobilized antibody to the CD3 antigen to deliver a suboptimal primary signal to the T cell. This system when presented along with B7 (CD80) co-stimulatory ligand provides a very potent signal through the CD28 receptor that initiates gene expression resulting in production of IL-2, T cell growth and other pro-inflammatory cytokines.

The fact that the antibodies of this invention have utility in inducing immunosuppression indicates that they should be useful in the treatment or prevention of resistance to or rejection of transplanted organs or tissues (e.g., kidney, heart, lung, bone marrow, skin, cornea, etc.); the treatment or prevention of autoimmune, inflammatory, proliferative and hyperproliferative diseases, and of cutaneous manifestations of immunologically mediated diseases (e.g., rheumatoid arthritis, lupus erythematosus, systemic lupus erythematosus, Hashimoto's thyroiditis, multiple sclerosis, myasthenia gravis, type 1 diabetes, uveitis, nephrotic syndrome, psoriasis, atopic dermatitis, contact dermatitis and further eczematous dermatitides, seborrheic dermatitis, Lichen planus, Pemphigus, bullous pemphigus, Epidermolysis bullosa, urticaria, angioedemas,

vasculitides, erythema, cutaneous eosinophilias, Alopecia areata, etc.); the treatment of reversible obstructive airways disease, intestinal inflammations and allergies (e.g., inflammatory bile disease, Coeliac disease, proctitis, eosinophilia gastroenteritis, mastocytosis, Crohn's disease and ulcerative colitis), food-related allergies (e.g., migraine, rhinitis and eczema), and other types of allergies.

One skilled in the art would be able, by routine experimentation, to determine what an effective, non-toxic amount of antibody would be for the purpose of inducing immunosuppression. Generally, however, an effective dosage will be in the range of about 0.05 to 100 milligrams per kilogram body weight per day.

The antibodies (or fragments thereof) of this invention should also be useful for treating tumors in a mammal. More specifically, they should be useful for reducing tumor size, inhibiting tumor growth and/or prolonging the survival time of tumor-bearing animals. Accordingly, this invention also relates to a method of treating tumors in a human or other animal by administering to such human or animal an effective, non-toxic amount of an antibody. One skilled in the art would be able, by routine experimentation, to determine what an effective, non-toxic amount of anti-B7 antibody would be for the purpose of treating carcinogenic tumors. Generally, however, an effective dosage is expected to be in the range of about 0.05 to 100 milligrams per kilogram body weight per day.

The antibodies of the invention may be administered to a human or other animal in accordance with the aforementioned methods of treatment in an amount sufficient to produce such effect to a therapeutic or prophylactic degree. Such antibodies of the invention can be administered to such human or other animal in a conventional dosage form prepared by combining the antibody of the invention with a conventional pharmaceutically acceptable carrier or diluent according to known techniques. It will be recognized by one of skill in the art that the form and character of the pharmaceutically acceptable carrier or diluent is dictated by the amount of active ingredient with which it is to be combined, the route of administration and other well-known variables.

The route of administration of the antibody (or fragment thereof) of the invention may be oral, parenteral, by inhalation or topical. The term parenteral as used herein includes intravenous, intraperitoneal, intramuscular, subcutaneous, rectal or vaginal administration. The subcutaneous and intramuscular forms of parenteral administration are generally preferred.

The daily parenteral and oral dosage regimens for employing compounds of the invention to prophylactically or therapeutically induce immunosuppression, or to therapeutically treat carcinogenic tumors will generally be in the range of about 0.05 to 100, but preferably about 0.5 to 10, milligrams per kilogram body weight per day.

The antibodies of the invention may also be administered by inhalation. By "inhalation" is meant intranasal and oral inhalation administration. Appropriate dosage

forms for such administration, such as an aerosol formulation or a metered dose inhaler, may be prepared by conventional techniques. The preferred dosage amount of a compound of the invention to be employed is generally within the range of about 10 to 100 milligrams.

5 The antibodies of the invention may also be administered topically. By topical administration is meant non-systemic administration and includes the application of an antibody (or fragment thereof) compound of the invention externally to the epidermis, to the buccal cavity and instillation of such an antibody into the ear, eye and nose, and where it does not significantly enter the blood stream. By systemic administration is meant oral, intravenous, intraperitoneal and intramuscular administration. The amount of an antibody required for therapeutic or prophylactic effect will, of course, vary with the antibody chosen, the nature and severity of the condition being treated and the animal undergoing treatment, and is ultimately at the discretion of the physician. A suitable topical dose of an antibody of the invention will generally be within the range of about 1 to 100 milligrams per kilogram body weight daily.

Formulations

While it is possible for an antibody or fragment thereof to be administered alone, it is preferable to present it as a pharmaceutical formulation. The active ingredient may comprise, for topical administration, from 0.001% to 10% w/w, e.g., from 1% to 2% by

weight of the formulation, although it may comprise as much as 10% w/w but preferably not in excess of 5% w/w and more preferably from 0.1% to 1% w/w of the formulation.

The topical formulations of the present invention, comprise an active ingredient together with one or more acceptable carrier(s) therefor and optionally any other therapeutic ingredients(s). The carrier(s) must be "acceptable" in the sense of being compatible with the other ingredients of the formulation and not deleterious to the recipient thereof.

Formulations suitable for topical administration include liquid or semi-liquid preparations suitable for penetration through the skin to the site of where treatment is required, such as liniments, lotions, creams, ointments or pastes, and drops suitable for administration to the eye, ear or nose.

Drops according to the present invention may comprise sterile aqueous or oily solutions or suspensions and may be prepared by dissolving the active ingredient in a suitable aqueous solution of a bactericidal and/or fungicidal agent and/or any other suitable preservative, and preferably including a surface active agent. The resulting solution may then be clarified by filtration, transferred to a suitable container which is then sealed and sterilized by autoclaving or maintaining at 90°-100°C for half an hour. Alternatively, the solution may be sterilized by filtration and transferred to the container by an aseptic technique. Examples of bactericidal and fungicidal agents suitable for inclusion in the drops are phenylmercuric nitrate or acetate (0.002%), benzalkonium

chloride (0.01%) and chlorhexidine acetate (0.01%). Suitable solvents for the preparation of an oily solution include glycerol, diluted alcohol and propylene glycol.

Lotions according to the present invention include those suitable for application to the skin or eye. An eye lotion may comprise a sterile aqueous solution optionally containing a bactericide and may be prepared by methods similar to those for the preparation of drops. Lotions or liniments for application to the skin may also include an agent to hasten drying and to cool the skin, such as an alcohol or acetone, and/or a moisturizer such as glycerol or an oil such as castor oil or arachis oil.

Creams, ointments or pastes according to the present invention are semi-solid formulations of the active ingredient for external application. They may be made by mixing the active ingredient in finely-divided or powdered form, alone or in solution or suspension in an aqueous or non-aqueous fluid, with the aid of suitable machinery, with a greasy or non-greasy basis. The basis may comprise hydrocarbons such as hard, soft or liquid paraffin, glycerol, beeswax, a metallic soap; a mucilage; an oil of natural origin such as almond, corn, arachis, castor or olive oil; wool fat or its derivatives, or a fatty acid such as stearic or oleic acid together with an alcohol such as propylene glycol or macrogols. The formulation may incorporate any suitable surface active agent such as an anionic, cationic or non-ionic surface active such as sorbitan esters or polyoxyethylene derivatives thereof. Suspending agents such as natural gums, cellulose derivatives or

inorganic materials such as siliceous silicas, and other ingredients such as lanolin, may also be included.

The subject anti-B7.1 antibodies or fragments thereof may also be administered in combination with other moieties which modulate the B7:CD28 pathway. Such moieties include, by way of example, cytokines such as IL-7 and IL-10, CTLA4-Ig, soluble CTLA-4 and anti-CD28 antibodies and fragments thereof. Also, the subject antibodies may be administered in combination with other immunosuppressants. Such immunosuppressants include small molecules such as cyclosporin A (CSA) and FK506; monoclonal antibodies such as anti-tumor necrosis factor α (anti-TNF α), anti-CD54, anti-CD11, anti-CD11a, and anti-IL-1; and, other soluble receptors such as rTNF α and rIL-1.

It will be recognized by one of skill in the art that the optimal quantity and spacing of individual dosages of an antibody or fragment thereof of the invention will be determined by the nature and extent of the condition being treated, the form, route and site of administration, and the particular animal being treated, and that such optimums can be determined by conventional techniques. It will also be appreciated by one of skill in the art that the optimal course of treatment, i.e., the number of doses of an antibody or fragment thereof of the invention given per day for a defined number of days, can be ascertained by those skilled in the art using conventional course of treatment determination tests.

Without further elaboration, it is believed that one skilled in the art can, using the preceding description, utilize the present invention to its fullest extent. The following formulations are, therefore, to be construed as merely illustrative embodiments and not a limitation of the scope of the present invention in any way.

Capsule Composition

A pharmaceutical composition of this invention in the form of a capsule is prepared by filling a standard two-piece hard gelatin capsule with 50 mg. of an antibody or fragment thereof of the invention, in powdered form, 100 mg. of lactose, 32 mg. of talc and 8 mg. of magnesium stearate.

Injectable Parenteral Composition

A pharmaceutical composition of this invention in a form suitable for administration by injection is prepared by stirring 1.5% by weight of an antibody or fragment thereof of the invention in 10% by volume propylene glycol and water. The solution is sterilized by filtration.

Ointment Composition

Antibody or fragment thereof of the invention 1.0 g.

White soft paraffin to 100.0 g.

The antibody or fragment thereof of the invention is dispersed in a small volume of the vehicle to produce a smooth, homogeneous product. Collapsible metal tubes are then filled with the dispersion.

Topical Cream Composition

Antibody or fragment thereof of the invention 1.0 g.

Polawax GP 200 20.0 g.

Lanolin Anhydrous 2.0 g.

White Beeswax 2.5 g.

Methyl hydroxybenzoate 0.1 g.

Distilled Water to 100.0 g.

The polawax, beeswax and lanolin are heated together at 60°C. A solution of methyl hydroxybenzoate is added and homogenization is achieved using high speed stirring. The temperature is then allowed to fall to 50°C. The antibody or fragment thereof of the invention is then added and dispersed throughout, and the composition is allowed to cool with slow speed stirring.

Topical Lotion Composition

Antibody or fragment thereof of the invention 1.0 g.

Sorbitan Monolaurate 0.6 g.

Polysorbate 20 0.6 g.

Cetostearyl Alcohol 1.2 g.

Glycerin 6.0 g.

Methyl Hydroxybenzoate 0.2 g.

Purified Water B.P. to 100-00 ml. (B.P. = British Pharmacopeia)

The methyl hydroxybenzoate and glycerin are dissolved in 70 ml. of the water at 75°C. The sorbitan monolaurate, polysorbate 20 and cetostearyl alcohol are melted together at 75°C and added to the aqueous solution. The resulting emulsion is homogenized, allowed to cool with continuous stirring and the antibody or fragment

thereof of the invention is added as a suspension in the remaining water. The whole suspension is stirred until homogenized.

Eye Drop Composition

Antibody or fragment thereof of the invention 0.5 g.

Methyl Hydroxybenzoate 0.01 g.

Propyl Hydroxybenzoate 0.04 g.

Purified Water B.P. to 100-00 ml.

The methyl and propyl hydroxybenzoates are dissolved in 70 ml. purified water at 75°C and the resulting solution is allowed to cool. The antibody or fragment thereof of the invention is then added, and the solution is sterilized by filtration through a membrane filter (0.022 µm pore size), and packed aseptically into suitable sterile containers.

Composition for Administration by Inhalation

For an aerosol container with a capacity of 15-20 ml: mix 10 mg. of an antibody or fragment thereof of the invention with 0.2-0.5% of a lubricating agent, such as polysorbate 85 or oleic acid, and disperse such mixture in a propellant, such as freon, preferably in a combination of (1,2 dichlorotetrafluoroethane) and difluorochloromethane and put into an appropriate aerosol container adapted for either intranasal or oral inhalation administration.

Composition for Administration by Inhalation

For an aerosol container with a capacity of 15-20 ml: dissolve 10 mg. of an antibody or fragment thereof of the invention in ethanol (6-8 ml.), add 0.1-0.2% of a lubricating agent, such as polysorbate 85 or oleic acid; and disperse such in a propellant, such as freon, preferably in combination of (1,2 dichlorotetra-fluoroethane) and difluorochloromethane, and put into an appropriate aerosol container adapted for either intranasal or oral inhalation administration.

The antibodies and pharmaceutical compositions of the invention are particularly useful for parenteral administration, i.e., subcutaneously, intramuscularly or intravenously. The compositions for parenteral administration will commonly comprise a solution of an antibody or fragment thereof of the invention or a cocktail thereof dissolved in an acceptable carrier, preferably an aqueous carrier. A variety of aqueous carriers may be employed, e.g., water, buffered water, 0.4% saline, 0.3% glycine, and the like. These solutions are sterile and generally free of particulate matter. These solutions may be sterilized by conventional, well-known sterilization techniques. The compositions may contain pharmaceutically acceptable auxiliary substances as required to approximate physiological conditions such as pH adjusting and buffering agents, etc. The concentration of the antibody or fragment thereof of the invention in such pharmaceutical formulation can vary widely, i.e., from less than about 0.5%, usually at or at least about 1% to as much as 15 or 20% by weight, and will be selected primarily

based on fluid volumes, viscosities, etc., according to the particular mode of administration selected.

Thus, a pharmaceutical composition of the invention for intramuscular injection could be prepared to contain 1 Ml sterile buffered water, and 50 mg. of an antibody or fragment thereof of the invention. Similarly, a pharmaceutical composition of the invention for intravenous infusion could be made up to contain 250 ml. of sterile Ringer's solution, and 150 mg. of an antibody or fragment thereof of the invention. Actual methods for preparing parenterally administrable compositions are well known or will be apparent to those skilled in the art, and are described in more detail in, for example, *Remington's Pharmaceutical Science*, 15th ed., Mack Publishing Company, Easton, Pennsylvania, hereby incorporated by reference herein.

The antibodies (or fragments thereof) of the invention can be lyophilized for storage and reconstituted in a suitable carrier prior to use. This technique has been shown to be effective with conventional immune globulins and art-known lyophilization and reconstitution techniques can be employed.

Depending on the intended result, the pharmaceutical composition of the invention can be administered for prophylactic and/or therapeutic treatments. In therapeutic application, compositions are administered to a patient already suffering from a disease, in an amount sufficient to cure or at least partially arrest the disease and its complications. In prophylactic applications, compositions containing the present antibodies or a cocktail

thereof are administered to a patient not already in a disease state to enhance the patient's resistance.

Single or multiple administrations of the pharmaceutical compositions can be carried out with dose levels and pattern being selected by the treating physician. In any event, the pharmaceutical composition of the invention should provide a quantity of the altered antibodies (or fragments thereof) of the invention sufficient to effectively treat the patient.

It should also be noted that the antibodies of this invention may be used for the design and synthesis of either peptide or non-peptide compounds (mimetics) which would be useful in the same therapy as the antibody. See, e.g., Saragovi et al., *Science*, 253, 792-795 (1991).

To further illustrate the invention, the following examples are provided. These examples are not intended, nor are they to be construed, as further limiting the invention.

EXAMPLE 1

Recombinant immunoglobulin libraries displayed on the surface of filamentous phage were first described by McCafferty et al, *Nature*, 348:552-554, 1990 and Barbas et al, *Proc. Natl. Acad. Sci., USA* 88:7978-7982, 1991. Using this technology, high affinity antibodies have been isolated from immune human recombinant libraries (Barbas et al, *Proc. Natl. Acad. Sci., USA* 89:10164-10168, 1992). Although the phage display concept used is substantially similar to that described by Barbas, 1991, Id. the technique

has been modified by the substitution of a unique vector for monkey libraries to reduce the possibility of recombination and improve stability. This vector, pMS, Figure 1 contains a single lac promoter/operator for efficient transcription and translation of polycistronic heavy and light chain monkey DNA. This vector contains two different leader sequences, the omp A (Movva et al, *J. Biol. Chem.* 255: 27-29 (1980), for the light chain and the pel B (Lei, *J. Bact.*, 4379-109:4383 (1987) for the heavy chain Fd. Both leader sequences are translated into hydrophobic signal peptides that direct the secretion of the heavy and light chain cloned products into the periplasmic space. In the oxidative environment of the periplasm, the two chains fold and disulfide bonds form to create stable Fab fragments. We derived the backbone of the vector from the phagemid bluescript. (Stratagene, La Jolla, CA). It contains the gene for the enzyme beta-lactamase that confers ampicillin (carbenicillin) resistance to bacteria that harbor pMS DNA. We also derived, from bluescript, the origin of replication of the multicopy plasmid ColEI and the origin of replication of the filamentous bacteriophage f1. The origin of replication of phage f1 (the so-called intragenic region), signals the initiation of synthesis of single stranded pMS DNA, the initiation of capsid formation and the termination of RNA synthesis by viral enzymes. The replication and assembly of pMS DNA strands into phage particles requires viral proteins that must be provided by a helper phage. We have used helper phage VCSM13 which is particularly suited for this, since it also contains a gene coding for kanamycin resistance. Bacteria infected with VCSM13 and pMS can be

selected by adding both kanamycin and carbenicillin to the growth medium. The bacteria will ultimately produce filamentous phage particles containing either pMS or VCSM13 genomes. Packaging of the helper phage is less efficient than that of pMS, resulting in a mixed phage population that contains predominately recombinant pMS phages. The ends of the phage pick up minor coat proteins specific to each end. Of particular interest here is the gene III product which is present in three to five copies at one end of the phage. The gene III product is 406 amino acid residues and is required for phage infection of *E. coli* via the F pili. The first two domains of the heavy chain, the variable and the CH1 domain, are fused to the carboxy-terminal half of the gene III protein. This recombinant pili protein, directed by the pel B leader, is secreted to the periplasm where it accumulates and forms disulfide bonds with the light chain before it is incorporated in the coat of the phage. Also, another vector contains a FLAG sequence engineered downstream of the gene III. The FLAG is an 8 amino acid peptide expressed at the carboxy terminal of the Fd protein. We are using commercially available monoclonal anti-FLAG M2 for both purification and detection of phage Fab by ELISA (Brizzard, *Bio Techniques* 16(4):730-731 (1994)).

After constructing the vector pMS, we tested its ability to produce phage bound Fab using control antibody genes. We cloned an anti-tetanus toxoid antibody, (obtained from Dr. Carlos Barbas), into pMS and transformed XLI-blue. We co-infected our cells with VCSM13 and generated phage displaying the anti-tetanus toxoid antibody. We

performed efficiency experiments where anti-tetanus toxoid phage were combined with phage beading an irrelevant antibody at 1:100,000. We performed three rounds of panning by applying 50 µl of the mixed phage to antigen (tetanus toxoid) coated polystyrene wells. Non-adherent phage were washed off and the adherent phage were eluted with acid. The eluted phage were used to infect a fresh aliquot of XL1Blue bacteria and helper phage was added. After overnight amplification, phage were prepared and again panned on antigen coated plates. After three rounds of panning, we were able to show that we had successfully enriched for the anti-tetanus toxoid phage. The success of this technology also depends on the ability to prepare soluble Fabs for characterization of the final panned product. This was achieved by excising gene III from the pMS DNA using the restriction enzyme Nhe I followed by re-ligation. After the gene III was excised, the Fab was no longer displayed on the phage surface but accumulated in the periplasmic space. Lysates were prepared from bacteria expressing soluble Fab and tested for antigen specificity using an ELISA. High levels of soluble Fab were detected.

In order to adapt phage display technology for use with macaque libraries, we developed specific primers for PCR amplifying monkey immunoglobulin genes. These were based on macaque sequences we obtained while developing the PRIMATIZED® antibody technology (*See*, U.S. Patent No. 5,658,570) and databases containing human sequences. (Kabat et al, (1991), "Sequences of Proteins of Immunological Interest," U.S. Dept. of Health and Human Services, National Institute of Health).

We developed three sets of primers to cover amplification of the macaque repertoire. Our first set of primers was designed for amplification of the heavy chain VH and CH1 (Fd) domains. It consisted of a 3' CH1 domain primer and six 5' VH family specific primers that bind in the framework 1 region. Our second set of primers, for amplifying the whole lambda chain, covers the many lambda chain subgroups. It consists of a 3' primer and three 5' degenerate primers that bind in the VL framework 1 region. Our third set of primers was designed for amplification of the kappa chain subgroups. It consists of one 3' primer and five VK framework 1 primers. Using each of these sets, PCR parameters were optimized to obtain strong enough signals from each primer pair so that ample material was available for cloning of the library. We recently created macaque combinatorial libraries in our pMS vector using these optimized PCR conditions. Bone marrow biopsies were taken from CD4 immune monkeys as the source of immunoglobulin RNA. The libraries contained approximately 10^6 members and are currently being panned for specific binders on antigen coated wells.

EXAMPLE 2

Development of B7/CTLA-4 Reagents

We have generated a number of reagents for the purpose of immunizing monkeys, developing binding and functional assays *in vitro*, screening heterohybridomas and panning phage libraries. Table 1 lists each reagent and its intended purpose. In the case

of B7.1, RNA was extracted from SB cells and converted to cDNA using reverse transcriptase. The first strand cDNA was PCR amplified using B7.1 specific primers and cloned into IDEC's NEOSPLA mammalian expression vectors. CHO cells were transfected with B7.1 NEOSPLA DNA and clones expressing membrane associated B7.1 were identified. The B7.1 fusion protein was generated similarly, except that the PCR amplified B7.1 gene was cloned into a NEOSPLA cassette vector containing the human CH2 and CH3 immunoglobulin genes. CHO cells were transformed with the B7.1/Ig NEOSPLA DNA and stable clones secreting B7.1/Ig fusion protein were amplified. In general, the B7.2 and CTLA4 reagents were generated in the same manner, except that for B7.2 the RNA was isolated from human spleen cells that had been stimulated 24 hours with anti-Ig and IL-4, and for the CTLA4 constructs the gene source was PHA activated human T cells.

TABLE 1

Reagent	Purpose	CHO Expression
Soluble B7.1	Immunization, immunoassays	Yes
B7.1 Transfectant	Screening, ELISA	Yes
B7.1/Ig Fusion Protein	Inhibition studies, panning	Yes
B7.2 Transfectant	Screening, ELISA	Yes
B7.2/Ig Fusion Protein	Inhibition studies, panning	To be completed
CTLA4 Transfectant	Inhibition studies	To be completed
CTLA4/Ig	Inhibition studies	To be completed

The availability of these reagents, together with monoclonal antibodies to B7.1 (L3074) (Becton Dickinson, 1994) and B7.2 (Fun-1 (Engel et al, Blood, 84, 1402-1407, (1994) and purified goat and rabbit antisera, specifically developed to detect monkey Fab fragments, facilitates identification of antibodies having the desired properties.

EXAMPLE 3

Generation of a Phage Display Library

Recombinant phage display libraries are generated from B7.1 and B7.2 immune monkeys. Lymph node and bone marrow biopsies are performed 7-12 days after immunization to harvest RNA rich B cells and plasma cells. RNA is isolated from the lymphocytes using the method described by Chomczynski, *Anal. Biochem.*, 162(1), 156-159 (1987). RNA is converted to cDNA using an oligo dT primer and reverse transcriptase. The first strand cDNA is divided into aliquots and PCR amplified using the sets of kappa, lambda, and heavy chain Fd region primers described earlier and either Pfu polymerase (Stratagene, San Diego) or Taq polymerase (Promega, Madison). The heavy chain PCR amplified products are pooled, cut with Xho VSpe I restriction enzymes and cloned into the vector pMS. Subsequently, the light chain PCR products are pooled, cut with Sac I/Xba I restriction enzymes, and cloned to create the recombinant library. XLI-Blue *E. coli* is transformed with the library DNA and super-infected with VCSM13 to produce the phage displaying antibodies. The library is panned four rounds on polystyrene wells coated with B7.1 or B7.2 antigen. Individual phage clones from each

round of panning are analyzed. The pMS vector DNA is isolated and the gene III excised. Soluble Fab fragments are generated and tested in ELISA for binding to B7.1 and B7.2.

EXAMPLE 4

Characterization of Phage Fab Fragments

The monkey phage Fab fragments are characterized for their specificity and the ability to block B7.1-Ig and B7.2-Ig binding to CTLA-4-Ig or CTLA-4 transfected cells. Phage fragments are also characterized for cross-reactivity after first panning for 4 rounds on the B7 species used for immunization in order to select for high affinity fragments. Fab fragments identified from four rounds of panning either on B7.1 or B7.2 antigen coated surfaces are scaled up by infection and grown in 24 hour fermentation cultures of E coli. Fragments are purified by Kodak FLAG binding to a anti-FLAG affinity column. Purified phage Fabs are tested for affinity by an ELISA based direct binding modified Scatchard analysis (Kato et al, *J. Chem. BioEng.* 76:451-454 (1993)) using Goat anti-monkey Fab antibodies or anti-FLAG MAb conjugated with horseradish peroxidase. The anti-monkey Fab reagents will be absorbed against human heavy chain constant region Ig to remove any cross-reactivity to B7-Ig. Kd values are calculated for each fragment after measurements of direct binding to B7.1-Ig or B7.2-Ig coated plates.

EXAMPLE 5

Phage Fab Fragment Blocking of CTLA-4/B7 Binding

Fab fragments most effectively blocking the binding of B7-Ig at the lowest concentrations are selected as lead candidates. Selections are made by competing off ¹²⁵I-B7-Ig binding to CTLA-4-Ig or CTLA-4 transfected cells. Additional selection criteria include, blocking of mixed lymphocyte reaction (MLR), as measured by inhibiting 3H-thymidine uptake in responder cells (Azuma et al, *J. Exp. Med.* 177:845-850; Azuma et al, *Nature* 301:76-79 (1993)) and direct analysis of IL-2 production using IL-2 assay kits. The three or four candidates which are most effective in inhibiting of MLR and CTLA-4 binding assays are chosen for cloning into the above-described mammalian expression vector for transfection into CHO cells and expression of chimeric monkey/human antibodies.

EXAMPLE 6

Generation of Monkey Heterohybridomas

Monkey heterohybridomas secreting monoclonal antibodies are generated from existing immunized animals whose sera tested positive for B7.1 and/or B7.2. Lymph node biopsies are taken from animals positive to either, or both, antigens. The method of hybridoma production is similar to the established method used for the generation of monkey anti-CD4 antibodies (Newman, 1992 (*Id.*)). Monkeys with high serum titers will have sections of inguinal lymph nodes removed under anesthesia. Lymphocytes are

washed from the tissue and fused with KH6/B5 heteromyeloma cells (Carrol et al, *J. Immunol. Meth.* 89:61-72 (1986)) using polyethylene glycol (PEG). Hybridomas are selected on H.A.T. media and stabilized by repeated subcloning in 96 well plates.

Monkey monoclonal antibodies specific for B7.1 antigen are screened for cross-reactivity to B7.2. Monkey anti-B7 antibodies will be characterized for blocking of B7/CTLA-4 binding using the ^{125}I -B7-Ig binding assay. Inhibition of MLR by 3H-Thymidine uptake and direct measurement of IL-2 production is used to select three candidates. Two candidates will be brought forward in Phase II studies and expressed in CHO cells while repeating all functional studies. For the purposes of developing an animal model for *in vivo* pharmacology, anti-B7 antibodies will be tested on cells of several animal species. The establishment of an animal model will allow preclinical studies to be carried out for the selected clinical indication.

EXAMPLE 7

As discussed *supra*, using the above heterohybridoma methods, 4 lead monkey anti-B7.1 antibodies have been identified: 16C10, 7B6, 7C10 and 20C9. These antibodies were characterized as follows:

Scatchard analysis showed that the apparent affinity constants (Kd) for the monkey antibodies binding to B7-Ig coated plates were approximated to be:

- a: 7C10: $6.2 \times 10^{-9}\text{M}$
- b: 16C10: $8.1 \times 10^{-9}\text{M}$
- c: 7B6: $10.7 \times 10^{-9}\text{M}$
- d: 20C9: $16.8 \times 10^{-9}\text{M}$

The antibodies were tested *in vitro* in a mixed lymphocyte reaction assay (MLR). The MLR showed that all 4 anti-B7.1 antibodies inhibit IL-2 production to different extents:

- a: 7B6: 5.0 µg/Ml
- b: 16C10: 0.1 µg/Ml
- c: 20C9: 2.0 µg/Ml
- d: 7C10: 5.0 µg/Ml

The monkey anti-B7.1 antibodies were tested for their ability to bind B7 on human peripheral blood lymphocytes (PBL). FACS analysis showed that all 4 monkey antibodies tested positive.

Monkey antibodies 16C10, 7B6, 7C10 and 20C9 were tested for C1q binding by FACS analysis. Results showed 7C10 monkey Ig had strong human C1q binding after incubating with B7.1 CHO-transfected cells. 16C10 was also positive, while 20C9 and 7B6 monkey antibodies were negative.

EXAMPLE 8

Using the primatized antibody methodology incorporated by reference to commonly assigned U.S. Patent No. 5,658,570, and using the NEOSPLA vector system shown in Figure 2, the heavy and light variable domains of 7C10, 7B6 and 16C10 were cloned and primatized forms thereof have been synthesized in CHO cells using the NEOSPLA vector system. The amino acid and nucleic acid sequences for the primatized 7C10 light and heavy chain, 7B6 light and heavy chain, and 16C10 light and heavy chain are respectively shown in Figures 3a, 3b, 4a, 4b, 5a and 5b.

EXAMPLE 9

Confirming experiments on the non-cross-reactivity of the CTLA-4 and PRIMATIZED® antibody binding sites on B7.1.

5 In competitive binding assays using biotinylated CTLA-4Ig (Figure 6), unlabeled primatized 16C10 (i.e., P16C10) was unable to block CTLA-4Ig binding to B7.1 transfected CHO cells. It can be seen that unlabeled CTLA-4Ig and unlabeled B7.1 effectively compete under these conditions.

10 In a second experiment using Biotinylated P16C10, the same conclusions can be made. In the experiment shown in Figure 7, binding of P16C10-Biotin is inhibited by both unlabeled P16C10 and B7.1Ig, but not by CTLA-4Ig. Although CTLA-4Ig is reported to be as much as 4-10 fold higher in affinity ($K_d=0.4$ nM; Morton et al., *J. Immunol.* 156:1047-1054 (1996)), there is no significant inhibition of P16C10 binding even at CTLA-4Ig concentrations as high as 100 fold excess.

15 Similar results were obtained using the primatized antibody 7C10 (P7C10) when it was substituted for P16C10 in the experiments (data not provided).

EXAMPLE 10

Comparing the ability of L307.4 and BB-1 mouse antibodies to bind to B7 CHO cells in the presence of CTLA-4Ig.

20 The binding of L307.4 and BB-1 murine anti-B7 antibody in the presence of CTLA-4Ig was studied in order to determine whether the mouse antibody binding sites overlapped with the CTLA-4 binding site. Competition assay experiments using P16C10-

Biotin, L307.4-Biotin and CTLA-4Ig-Biotin were done to insure that affinity differences did not prevent detection of competitive binding. The results are shown in Figures 8 and 9.

The results of Figure 8 confirm earlier studies that the mouse antibody BB-1 does not compete with P16C10. These results also show that there is some cross-reactivity to L307.4 of approximately 50%. The results of Figure 8 confirm that BB-1 and L307.4 both compete with each other and that BB-1 completely blocks binding of CTLA-4Ig-Biotin to B7.1 transfected CHO cells. BB-1 does not significantly affect P16C10 binding to B7.1 positive CHO cells.

The results shown in Figure 9 indicate better than 50% competition when CTLA-4Ig-Biotin is used in the binding experiment. Figure 9 shows that CTLA-4Ig-Biotin is effectively blocked by all B7.1 inhibitors except P16C10, therefore P16C10 recognizes a unique binding determinate on B7.1 which allows the normal CTLA-4 ligand binding in the generation of negative signals. Earlier functional studies (data not shown) suggest a weakened ability of L307.4 to block IL-2 production in allogeneic MLR, which correlates with the hypothesis that it may interfere with CTLA-4 negative signaling. It is not clear how many of the other murine antibodies reported in the literature give complete inhibition of CTLA-4 binding; however, this issue may be important in defining the true functional mechanisms of B7.1 and B7.2 specific antibodies.

These results confirm earlier studies using B7-Ig in competition with P16C10-Biotin for binding to B7.1 transfected CHO cells. The studies also confirm earlier observations of no inhibition of the P16C10 by CTLA-4Ig. These results are highly suggestive that the primate antibodies are specific for a unique B7.1 epitope independent of the CTLA-4 binding site which interacts primarily with CD28. This type of interaction would provide a benefit, since it has the ability to block binding of B7.1 to CD28 receptors while still allowing the negative signaling function of CTLA-4 to occur uninhibited. This perceived interaction may lead to a down regulation of the overall T cell activation response regardless of the predominance of either Th1 or Th2 phenotypes.

Similar results were obtained using P7C10 when it was substituted for P16C10 in the experiments (data not provided).

EXAMPLE 11

Experiment demonstrating the ability of P16C10 to bind and block B7.1 interactions with CD28 receptor.

An experiment to determine if P16C10 binding of B7.1 can block the interaction of B7.1 with CD28 was attempted by radiolabeling B7.1Ig with ^{125}I , followed by competitive binding to CD28 positive non-activated peripheral blood T lymphocytes. The results shown in Figure 10 demonstrate that the radiolabeled B7.1Ig binds specifically to the T cells, as confirmed by inhibition with unlabeled B7.1Ig. The results also show that CTLA-4Ig, anti-CD28 and P16C10 are all capable of blocking this

interaction. The results further confirm that P16C10 blocks binding of the CD28/B7 interaction with an IC_{50} of $< 1 \text{ ug/mL}$.

The above results were obtained under conditions where no membrane associated CTLA-4 was expressed (Linsley et al., *J. Exp. Med.* 173:721-730 (1991)) and confirmed by blocking with the anti-CD28 antibody.

Similar results were obtained using P7C10 when it was substituted for P16C10 in the experiments (data not provided).

EXAMPLE 12

IDEC-114 does not block IL-2 production in co-stimulated T cells

In an experiment, the results of which are contained in Figure 11, a sub-optimal primary signal was induced by attaching an anti-CD3 antibody and a soluble B7Ig fusion protein to covalently coupled protein-A latex microspheres. Initially, a 1:10 ratio of anti-CD3 to B7Ig was used which is a relatively high density of B7 co-stimulatory molecules that is several times greater than normal cells express based on the relative amounts of IL-2 that are typically produced. Purified CD4⁺ T cells obtained from blood bank donors and co-cultured the cells in presence or absence of soluble CD28:B7 inhibitors that included anti CD80 antibodies L307.4 and IDEC-114 and soluble CTLA-4Ig fusion protein were added at three concentrations ranging from 10 to 0.1 $\mu\text{g/mL}$. Samples of tissue culture media were collected after 48 hours and the IL-2 cytokine present in the cultures was determined. The results show clearly that beads containing anti-CD3 alone

and B7Ig alone produced little or no IL-2. By contrast, both anti-CD3 and B7Ig were present approximately 4500 pg/mL of IL-2 was produced. The results also revealed that both L307.4 and CTLA-4Ig completely inhibited the production of IL-2 at all concentrations where IDEC-114 had no effect. These results suggest that L307.4 and CTLA-4Ig regulate the activation of T cells by a similar mechanism that directly interferes with CD28 signaling to produce the activating cytokine IL-2 while IDEC-114 has no such functional property.

EXAMPLE 13

IDEC-114 does not block growth in co-stimulated T cells

The same cultures were analyzed for effect on cell growth and similar results to the effects on IL-2 production were obtained. As seen in Figure 12, L307.4 and CTLA-4Ig were equally effective in totally blocking cell proliferation as determined by uptake of radiolabeled thymidine. Under these same conditions, IDEC-114 had no effect on cell growth. These results further suggest that IDEC-114 is not directly regulating the growth and differentiation properties of CD4⁺ T cells by blocking the interaction between B7(CD80) and CD28 receptors, unlike other tested anti-B7 antibodies having different binding specifications.

EXAMPLE 14

IDEC-114 partially blocks IL-10 production in co-stimulated T cells

The same cultures were analyzed for the presence of the secondary TH2 cytokine IL-10. It was found that both L307.4 and CTLA-4 again completely blocked IL-10 production, whereas IDEC-114 only partially blocked IL-10 proeduction. As seen in Figure 3, L307.4 and CTLA-4Ig were about equally effective in blocking IL-10 production while IDEC-114 had a partial effect. The partial inhibition of IL-10 by IDEC-114 may be a function of its property of allowing negative signaling to occur in T cells by not interfering with the function of CTLA-4 expressed in T cells. CTLA-4 is upregulated in T cells during co-stimulation and is thought to provide a negative signal to T cells. These results further suggest that IDEC-114 is not regulating the cytokine producing properties of CD4+ T cells through the normal channels involving CD28 signal transduction.

EXAMPLE 15

IDEC-114 blocks IL-2 production in T cells co-stimulated with micro-beads containing reduced amounts of B7.

In another experiment, the ratio of anti-CD3 to B7-Ig was adjusted on the stimulator beads from a 1:10 ratio to 8:1 or a reduction in B7 of about 80-fold with an 8-fold excess of anti-CD3. The production of IL-2 under these conditions is significantly reduced to typically less than 1000 pg/mL and is more in line with cultures stimulated with mismatched allotypes or CD80 transfected cells. Under these conditions (Figure

14), we observed near complete inhibition of IL-2 with CTLA-4Ig consistent with results obtained by beads with an anti-CD3/B7-Ig ratio of 1:10. However, with IDEC-114, we routinely observed significant inhibition of IL-2 (50-90%). We are also able to block IL-2 generated in cultures of mixed lymphocytes or when B7 transfected CHO cells are used as stimulators instead of microbeads.

These results suggest that IDEC-114 may function by interfering with adhesion and its effects may be facilitated by reduced expression or maintaining of a lower avidity form of CD80 during co-stimulation.

Analysis of Results

The T cell regulatory properties of IDEC- 1 14 and CTLA-4Ig were compared in an *in vitro* co-stimulatory system that includes purified CD4+ helper T cells in the absence of accessory cells. In place of accessory antigen-presenting cells, Protein A coated latex microspheres and attached anti-CD3 and B7Ig fusion protein were used. When T-cells were incubated with beads that contained a 10-fold excess of B7 there was a strong co-stimulatory response as measured by IL-2, IL-10 and cell growth that was totally blocked by CTLA-4Ig and a commercially available anti-CD80 monoclonal antibody L307.4. By contrast IDEC-114 had no effect on IL-2 or cell growth but did partially inhibit IL-10 production. It appears that both CTLA-4 and L307.4 possess higher affinities to B7 antigen and that increasing the concentration of IDEC-114 in the cultures should result in the same effect. Based thereon, the affinities of CTLA-4Ig and

IDEC-114 ($K_d=4$ nM) were compared by surface plasmon resonance. It was found that
 the affinity of CTLA-4Ig (Morten et al., 1996, *J. Immunol.* 156: 1047-1054) was
 approximately 10-fold higher ($K_d=0.4$ nM). This assay was performed using as much as
 1000-fold greater concentration of IDEC-114 with no effect on IL-2. Also, when T-cells
 were activated in cultures with beads containing a reduced content of B7 (anti-CD3/B7,
 8:1), significant blocking of IL-2 production by both CTLA-4Ig and IDEC- 114 was
 observed. In the latter experiment the equivalent blocking ability of IDEC-114 required
 approximately 10-fold higher concentration than CTLA-4Ig and was comparable to the
 difference between the affinities of the two. These results were interpreted by
 hypothesizing that reduced amounts of B7 on the beads may lead to a reduction in the
 forming of stable interactions with CD28. This low affinity state may somewhat
 resemble normal resting B cells. Therefore, with the reduced avidity for adhesion, IDEC-
 114 may bind to a remote site inducing a conformational change resulting in even lower
 affinity of CD80 for CD28.

Alternatively, antigen presenting cells that become activated may increase their
 surface density to the extent that the highly mobile B7 molecules more easily form
 homodimers. With respect thereto, it has been reported that monomeric forms of B7 have
 extremely low affinity and fast off-rate kinetics (van der Merwe, et al. 1997, *J. Exp. Med.*,
 185: 393-403) and that homodimeric forms can have up to 500-fold higher affinity. A
 higher affinity form would understandably facilitate cluster or patch formation leading

to a more stable receptor ligand complex. Consequently, IDEC-114 may bind to a remote site that could restrict the association of neighboring CD80 molecules and reduce or limit the amount of dimerization effectively limiting the adhesion complex formation.

5 The observed results suggest that primatized antibodies having the novel binding properties disclosed herein do not influence the regulation of T cells, unlike prior anti-B7.1 antibodies. It is hypothesized, based on these results, that the antibodies of the invention, such as IDEC - 114, bind to a unique site on CD80 expressed on antigen presenting cells which prevents the association of CD80 receptors from forming a higher affinity interaction with CD28 receptors on T cells. This would generate a weaker signal through CD28 that under certain conditions could not be overcome by the upregulation of more B7 ligand. However, these same results do not preclude the ability of IDEC-114 to function in other types of immune regulatory mechanisms occurring *in vivo* where the presence of NK cells and macrophages may contribute to killing of B cells or activated T cells through Fc and complement mediated effects.

15 It is anticipated that these primatized antibodies, given their probable low antigenicity and human effector function, will be well suited as therapeutics. In this regard, it has been shown that primatized 16C10 (IDEC - 114) exhibits human Clq binding.

Those skilled in the art will recognize or be able to ascertain using no more than routine experimentation many equivalents to the specific embodiments of the invention described herein. Such equivalents are intended to be embraced by the following claims.

WHAT IS CLAIMED IS:

1. A monoclonal antibody which specifically binds to B7.1 antigen (CD80) which antibody does not inhibit the binding of B7.1 antigen to CTLA-4.

2. The monoclonal antibody of Claim 1, which inhibits the production of IL-2 by T cells.

3. The monoclonal antibody of Claim 2, which selectively inhibits the interaction of B and T cells via the CD28/B7.1 pathway.

4. The monoclonal antibody of Claim 1, which is capable of inhibiting *in vitro* the production of IL-2 by T lymphocytes.

5. The monoclonal antibody of Claim 4, wherein said antibody is capable of inhibiting IL-2 production when added to a T lymphocyte containing culture at a concentration of at least 10 µg/ml.

6. A monoclonal antibody which binds to the same epitope on B7.1 as 16C10 or 7C10, or which monoclonal antibody inhibits the interaction of 16C10 or 7C10 with B7.1.

7. The monoclonal antibody of Claim 1, which is a primatized antibody.

8. The monoclonal antibody of Claim 1, which is a human, chimeric mouse/human, or humanized antibody.

9. The monoclonal antibody of Claim 1, wherein said B7.1 is human B7.1.

10. The monoclonal antibody of Claim 1, wherein said B7.2 is human B7.2.

11. A method of treating a disease involving T cell/B cell interactions comprising administering an amount of a monoclonal antibody according to Claim 1 sufficient to inhibit the binding of B cells and T cells via the B7.1/CD28 pathway.

12. The method of Claim 11, wherein said antibody is a primatized, humanized, or human monoclonal antibody.

13. The method of Claim 11, wherein said disease is an autoimmune disorder.
14. The method of Claim 12, wherein said disease is an autoimmune disorder.
15. The method of Claim 11, wherein said disease is selected from the group consisting of idiopathic thrombocytopenia purpura, systemic lupus erythematosus, type 1 diabetes mellitus, rheumatoid arthritis, psoriasis, aplastic anemia, inflammatory bile disease, allergy and multiple sclerosis.
16. The method of Claim 12, wherein said disease is selected from the group consisting of idiopathic thrombocytopenia purpura, systemic lupus erythematosus, type 1 diabetes mellitus, rheumatoid arthritis, psoriasis, aplastic anemia, inflammatory bile disease, allergy and multiple sclerosis.
17. The method of Claim 13, wherein said disease is graft-versus-host disease.
18. The method of Claim 14, wherein said disease is graft-versus-host disease.
19. The method of Claim 11, wherein said disease is selected from the group consisting of B cell lymphoma, infectious diseases, and inflammatory diseases.

20. The method of Claim 12, wherein said disease is selected from the group consisting of B cell lymphoma, infectious diseases, and inflammatory diseases.

21. A pharmaceutical composition suitable for treatment of a disease treatable by inhibition of B7:CD28 binding which comprises an antibody according to Claim 1.

22. The composition of Claim 21, wherein the composition further comprises another recombinant protein or small molecule immunosuppressants.

23. The method of Claim 11, wherein the antibody is administered in combination with other recombinant protein or small molecule immunosuppressants.

24. The antibody of Claim 1 which does not block IL2 production in cultures comprising anti-CD3 antibody/B7Ig co-stimulated T-cells.

25. The antibody of Claim 1, which does not inhibit growth and/or differentiation of anti-CD3 antibody/B7Ig co-stimulated T-cells.

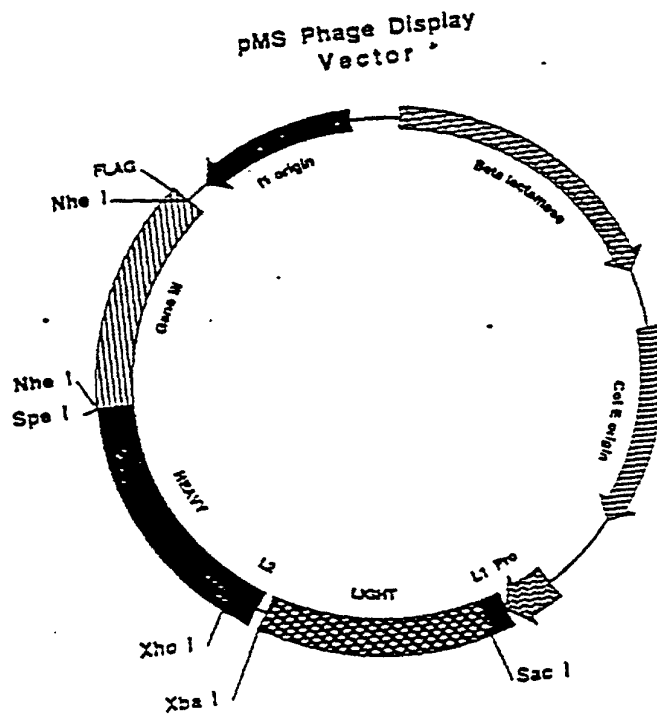
26. The antibody of Claim 1, which only partially blocks IL-10 production in a culture comprising anti-CD3 antibody/B7Ig co-stimulated T-cells.

ABSTRACT

The present invention relates to the identification of antibodies which are specific to human B7.1 antigen (CD80) and which are capable of inhibiting the binding of B7.1 to a CD28 receptor and which are not capable of inhibiting the binding of B7.1 to a CTLA-4 receptor. Two of these antibodies, 16C10 and 7C10, significantly inhibit the production of IL-2, in spite of the existence of a second activating ligand B7.2 (CD86). Blocking of the primary activation signal between CD28 and B7.1 (CD80) with these antibodies while allowing the unimpaired or coincident interaction of CTLA-4 and B7.1 and/or B7.2 represents a combined antagonistic effect on positive co-stimulation with an agonistic effect on negative signalling. These antibodies may be used as specific immunosuppressants, e.g., for the treatment of autoimmune diseases and to prevent organ transplant rejection.

FIGURE 1

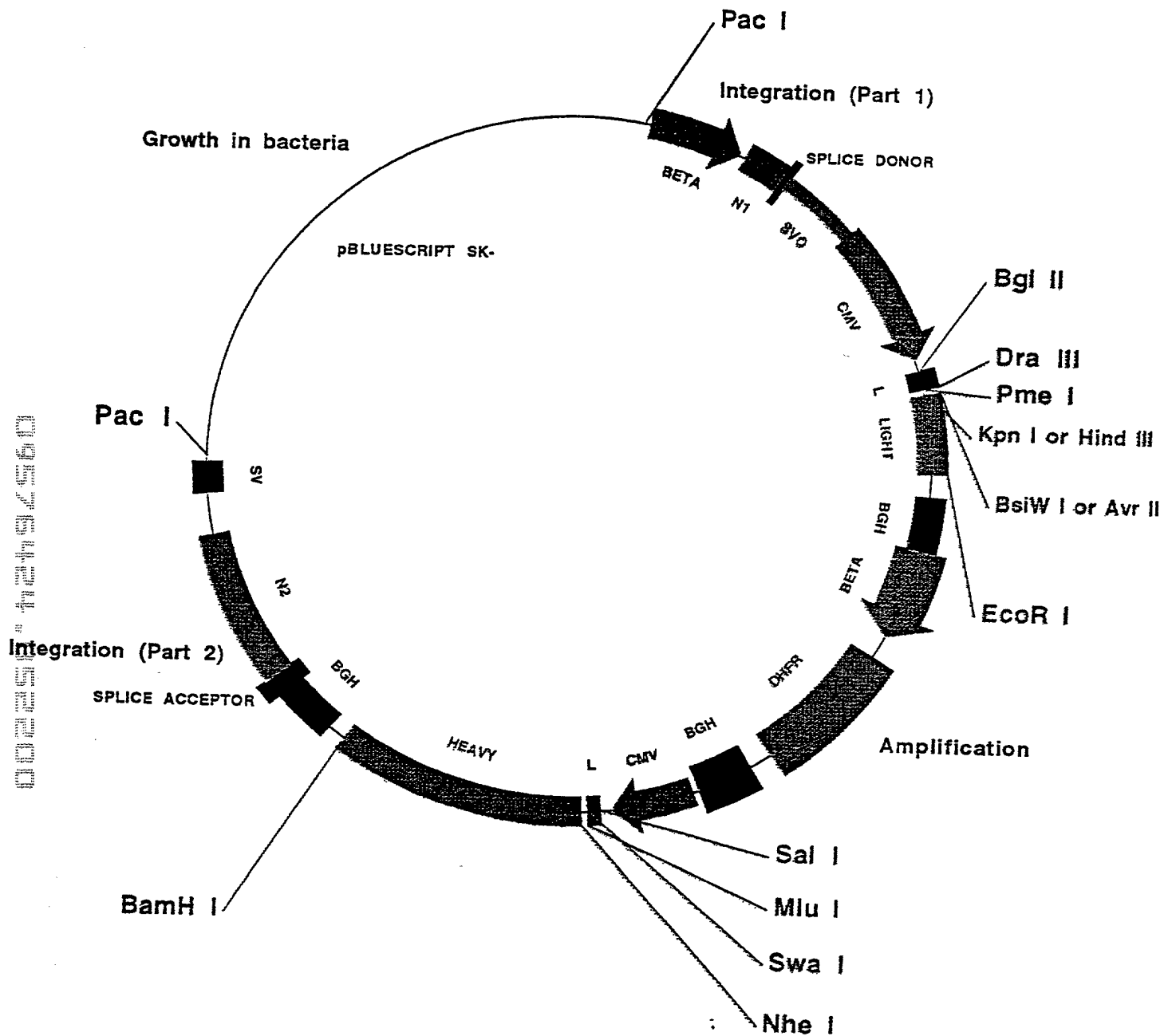
Figure 1: pMS Phage Display Vector. Pro = Lac Z promoter. L1 = Omp A leader. L2 = Pel B leader. Light = light chain. Heavy = heavy chain.



002250 052200 09576424

FIGURE 2

NEOSPLA



- CMV = Cytomegalovirus promoter/enhancer
- BETA = Mouse Beta globin major promoter
- SVO = SV40 origin
- BGH = Bovine growth hormone polyadenylation
- SV = SV40 polyadenylation
- N1 = Neomycin phosphotransferase exon 1
- N2 = Neomycin phosphotransferase exon 2
- LIGHT = Human immunoglobulin kappa or lambda constant region
- DHFR = Dihydrofolate Reductase
- HEAVY = Human immunoglobulin gamma 1 or gamma 4 PE constant region
- L = Leader

3a

Length of 7C10 light/Primatized: 705 bp; Listed from: 1 to: 705;

Translated from: 1 to: 703 (Entire region);

Genetic Code used: Universal; Fri, May 26, 1995 11:11 AM

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C	A	Y	E	L	T	Q	P	P	S	V	S	V	S	P	G	Q	T	A	R
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A	P	I	L	V	I	Y	D	D	S	D	R	P	S	G	I	P	E	R	F
GCC	CCT	ATA	CTG	GTC	ATC	TAT	GAT	GAT	AGT	GAC	CGG	CCC	TCA	GGG	ATC	CCT	GAG	CGA	TTC
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FIGURE 3b

Length of 7C10 heavy/Primatized: 1431 bp; Listed from: 1 to: 1431;
Translated from: 1 to: 1429 (Entire region);
Genetic Code used: Universal; Fri, May 26, 1995 11:11 AM

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F P P K P K D T L M I S R T P E V T C V V
TTC CCC CCA AAA CCC AAG GAC ACC CTC ATG ATC TCC CGG ACC CCT GAG GTC ACA TGC GTG GTG
819 828 837 846 855 864 873

V D V S H E D P E V K F N W Y V D G V E V
GTG GAC GTG AGC CAC GAA GAC CCT GAG GTC AAG TTC AAC TGG TAC GTG GAC GGC GTG GAG GTG
882 891 900 909 918 927 936

FIGURE 3b (Continued)

H	N	A	K	T	K	P	R	E	E	Q	Y	N	S	T	Y	R	V	V	S	V
CAT	AAT	GCC	AAG	ACA	AAG	CCG	CGG	GAG	GAG	CAG	TAC	AAC	AGC	ACG	TAC	CGT	GTG	GTC	AGC	GTC
945				954			963			972			981			990			999	
L	T	V	L	H	Q	D	W	L	N	G	K	E	Y	K	C	K	V	S	N	K
CTC	ACC	GTC	CTG	CAC	CAG	GAC	TGG	CTG	AAT	GGC	AAG	GAG	TAC	AAG	TGC	AAG	GTC	TCC	AAC	AAA
1008				1017			1026			1035			1044			1053			1062	
A	L	P	A	P	I	E	K	T	I	S	K	A	K	G	Q	P	R	E	P	Q
GCC	CTC	CCA	GCC	CCC	ATC	GAG	AAA	ACC	ATC	TCC	AAA	GCC	AAA	GGG	CAG	CCC	CGA	GAA	CCA	CAG
1071				1080			1089			1098			1107			1116			1125	
V	Y	T	L	P	P	S	R	D	E	L	T	K	N	Q	V	S	L	T	C	L
GTG	TAC	ACC	CTG	CCC	CCA	TCC	CGG	GAT	GAG	CTG	ACC	AAG	AAC	CAG	GTC	AGC	CTG	ACC	TGC	CTG
1134				1143			1152			1161			1170			1179			1188	
V	K	G	F	Y	P	S	D	I	A	V	E	W	E	S	N	G	Q	P	E	N
GTC	AAA	GGC	TTC	TAT	CCC	AGC	GAC	ATC	GCC	GTG	GAG	TGG	GAG	AGC	AAT	GGG	CAG	CCG	GAG	AAC
1197				1206			1215			1224			1233			1242			1251	
N	Y	K	T	T	P	P	V	L	D	S	D	G	S	F	F	L	Y	S	K	L
AAC	TAC	AAG	ACC	ACG	CCT	CCC	GTG	CTG	GAC	TCC	GAC	GGC	TCC	TTC	TTC	CTC	TAC	AGC	AAG	CTC
1260				1269			1278			1287			1296			1305			1314	
T	V	D	K	S	R	W	Q	Q	G	N	V	F	S	C	S	V	M	H	E	A
ACC	GTG	GAC	AAG	AGC	AGG	TGG	CAG	CAG	GGG	AAC	GTC	TTC	TCA	TGC	TCC	GTG	ATG	CAT	GAG	GCT
1323				1332			1341			1350			1359			1368			1377	
L	H	N	H	Y	T	Q	K	S	L	S	L	S	P	G	K					
CTG	CAC	AAC	CAC	TAC	ACG	CAG	AAG	AGC	CTC	TCC	CTG	TCT	CCG	GGT	AAA	TGA				
1386				1395			1404			1413			1422			1431				

002250042405200

FIGURE 4a

Length of 7B6 light/Primatized: 720 bp; Listed from: 1 to: 720;
 Translated from: 1 to: 718 (Entire region);
 Genetic Code used: Universal; Fri, May 26, 1995 11:10 AM

Frame 1 M S L P A Q L L G L L L L C V P G S S
 ATG AGC CTC CCT GCT CAG CTC CTC GGG CTG CTA TTG CTC TGC GTC CCC GGG TCC AGT
 9 18 27 36 45 54

G E V V M T Q S P L S L P I T P G E P A S
 GGG GAA GTT GTG ATG ACT CAG TCT CCA CTG TCC CTT CCC ATC ACA CCT GGA GAG CCG GCC TCC
 63 72 81 90 99 108 117

I S C R S S Q S L K H S N G D T F L S W Y
 ATC TCC TGT AGG TCT AGT CAA AGC CTT AAA CAC AGT AAT GGA GAC ACC TTC CTG AGT TGG TAT
 126 135 144 153 162 171 180

Q Q K P G Q P P R L L I Y K V S N R D S G
 CAG CAG AAG CCA GGC CAA CCT CCA AGG CTC CTG ATT TAT AAG GTT TCT AAC CGG GAC TCT GGG
 189 198 207 216 225 234 243

V P D R F S G S G A G T D F T L K I S A V
 GTC CCA GAC AGA TTC AGC GGC AGT GGG GCA GGG ACA GAT TTC ACA CTG AAA ATC AGC GCA GTG
 252 261 270 279 288 297 306

E A E D V G V Y F C G Q G T R T P P T F G
 GAG GCT GAA GAT GTT GGG GTT TAT TTC TGC GGG CAA GGT ACA AGG ACT CCT CCC ACT TTC GGC
 315 324 333 342 351 360 369

G G T K V E I K R T V A A P S V F I F P P
 GGA GGG ACC AAG GTG GAA ATC AAA CGT ACG GTG GCT GCA CCA TCT GTC TTC ATC TTC CCG CCA
 378 387 396 405 414 423 432

S D E Q L K S G T A S V V C L L N N F Y P
 TCT GAT GAG CAG TTG AAA TCT GGA ACT GCC TCT GTT GTG TGC CTG CTG AAT AAC TTC TAT CCC
 441 450 459 468 477 486 495

R E A K V Q W K V D N A L Q S G N S Q E S
 AGA GAG GCC AAA GTA CAG TGG AAG GTG GAT AAC GCC CTC CAA TCG GGT AAC TCC CAG GAG AGT
 504 513 522 531 540 549 558

V T E Q D S K D S T Y S L S S T L T L S K
 GTC ACA GAG CAG GAC AGC AAG GAC AGC ACC TAC AGC CTC AGC AGC ACC CTG ACG CTG AGC AAA
 567 576 585 594 603 612 621

A D Y E K H K V Y A C E V T H Q G L S S P
 GCA GAC TAC GAG AAA CAC AAA GTC TAC GCC TGC GAA GTC ACC CAT CAG GGC CTG AGC TCG CCC
 630 639 648 657 666 675 684

V T K S F N R G E C
 GTC ACA AAG AGC TTC AAC AGG GGA GAG TGT TGA
 693 702 711 720

FIGURE 4b

Length of 7B6 heavy/Primatized: 1437 bp; Listed from: 1 to: 1437;
 Translated from: 1 to: 1435 (Entire region);
 Genetic Code used: Universal; Fri, May 26, 1995 11:09 AM

Frame 1 M G W S L I L L F L V A V A T R V Q C
 ATG GGT TGG AGC CTC ATC TTG CTC TTC CTT GTC GCT GTT GCT ACG CGT GTC CAG TGT
 9 18 27 36 45 54

E V Q L V E S G G G L V Q P G G S L R V S
 GAG GTG CAA CTG GTG GAG TCT GGG GGA GGC TTG GTC CAG CCT GGC GGG TCC CTG AGA GTC TCC
 63 72 81 90 99 108 117

C A V S G F T F S D H Y M Y W F R Q A P G
 TGT GCA GTC TCT GGA TTC ACC TTC AGT GAC CAC TAC ATG TAT TGG TTC CGC CAG GCT CCA GGG
 126 135 144 153 162 171 180

K G P E W V G F I R N K P N G G T T E Y A
 AAG GGG CCG GAA TGG GTA GGT TTC ATT AGA AAC AAA CCG AAC GGT GGG ACA ACA GAA TAC GCC
 189 198 207 216 225 234 243

A S V K D R F T I S R D D S K S I A Y L Q
 GCG TCT GTG AAA GAC AGA TTC ACC ATC TCC AGA GAT GAT TCC AAA AGC ATC GCC TAT CTG CAA
 252 261 270 279 288 297 306

M S S L K I E D T A V Y Y C T T S Y I S H
 ATG AGC AGC CTG AAA ATC GAG GAC ACG GCC GTC TAT TAC TGT ACT ACA TCC TAC ATT TCA CAT
 315 324 333 342 351 360 369

C R G G V C Y G G Y F E F W G Q G A L V T
 TGT CGG GGT GGT GTC TGC TAT GGA GGT TAC TTC GAA TTC TGG GGC CAG GGC GCC CTG GTC ACC
 378 387 396 405 414 423 432

V S S A S T K G P S V F P L A P S S K S T
 GTC TCC TCA GCT AGC ACC AAG GGC CCA TCG GTC TTC CCC CTG GCA CCC TCC TCC AAG AGC ACC
 441 450 459 468 477 486 495

S G G T A A L G C L V K D Y F P E P V T V
 TCT GGG GGC ACA GCG GCC CTG GGC TGC CTG GTC AAG GAC TAC TTC CCC GAA CCG GTG ACG GTG
 504 513 522 531 540 549 558

S W N S G A L T S G V H T F P A V L Q S S
 TCG TGG AAC TCA GGC GCC CTG ACC AGC GGC GTG CAC ACC TTC CCG GCT GTC CTA CAG TCC TCA
 567 576 585 594 603 612 621

G L Y S L S S V V T V P S S S L G T Q T Y
 GGA CTC TAC TCC CTC AGC AGC GTG GTG ACC GTG CCC TCC AGC AGC TTG GGC ACC CAG ACC TAC
 630 639 648 657 666 675 684

I C N V N H K P S N T K V D K K A E P K S
 ATC TGC AAC GTG AAT CAC AAG CCC AGC AAC ACC AAG GTG GAC AAG AAA GCA GAG CCC AAA TCT
 693 702 711 720 729 738 747

C D K T H T C P P C P A P E L L G G P S V
 TGT GAC AAA ACT CAC ACA TGC CCA CCG TGC CCA GCA CCT GAA CTC CTG GGG GGA CCG TCA GTC
 756 765 774 783 792 801 810

F L F P P K P K D T L M I S R T P E V T C
 TTC CTC TTC CCC CCA AAA CCC AAG GAC ACC CTC ATG ATC TCC CGG ACC CCT GAG GTC ACA TGC
 819 828 837 846 855 864 873

V V V D V S H E D P E V K F N W Y V D G V
 GTG GTG GTG GAC GTG AGC CAC GAA GAC CCT GAG GTC AAG TTC AAC TGG TAC GTG GAC GGC GTG
 882 891 900 909 918 927 936

FIGURE 4b (Continued)

E V H N A K T K P R E E Q Y N S T Y R V V
 GAG GTG CAT AAT GCC AAG ACA AAG CCG CGG GAG GAG CAG TAC AAC AGC ACG TAC CGT GTG GTC
 945 954 963 972 981 990 999

S V L T V L H Q D W L N G K E Y K C K V S
 AGC GTC CTC ACC GTC CTG CAC CAG GAC TGG CTG AAT GGC AAG GAG TAC AAG TGC AAG GTC TCC
 1008 1017 1026 1035 1044 1053 1062

N K A L P A P I E K T I S K A K G Q P R E
 AAC AAA GCC CTC CCA GCC CCC ATC GAG AAA ACC ATC TCC AAA GCC AAA GGG CAG CCC CGA GAA
 1071 1080 1089 1098 1107 1116 1125

P Q V Y T L P P S R D E L T K N Q V S L T
 CCA CAG GTG TAC ACC CTG CCC CCA TCC CGG GAT GAG CTG ACC AAG AAC CAG GTC AGC CTG ACC
 1134 1143 1152 1161 1170 1179 1188

C L V K G F Y P S D I A V E W E S N G Q P
 TGC CTG GTC AAA GGC TTC TAT CCC AGC GAC ATC GCC GTG GAG TGG GAG AGC AAT GGG CAG CCG
 1197 1206 1215 1224 1233 1242 1251

E N N Y K T T P P V L D S D G S F F L Y S
 GAG AAC AAC TAC AAG ACC ACG CCT CCC GTG CTG GAC TCC GAC GGC TCC TTC TTC CTC TAC AGC
 1260 1269 1278 1287 1296 1305 1314

K L T V D K S R W Q Q G N V F S C S V M H
 AAG CTC ACC GTG GAC AAG AGC AGG TGG CAG CAG GGG AAC GTC TTC TCA TGC TCC GTG ATG CAT
 1323 1332 1341 1350 1359 1368 1377

E A L H N H Y T Q K S L S L S P G K
 GAG GCT CTG CAC AAC CAC TAC ACG CAG AAG AGC CTC TCC CTG TCT CCG GGT AAA TGA
 1386 1395 1404 1413 1422 1431

002250-0124-55

5a

Length of 16C10 Lambda/Primatized : 711 bp;

Listed from: 1 to: 711;

Translated from: 1 to: 709 (Entire region);

Genetic Code used: Universal; Fri, May 26, 1995 11:08 AM

Frame	1	M	R	V	P	A	Q	L	L	G	L	L	L	L	W	L	P	G	A	R
	ATG	AGG	GTC	CCC	GCT	CAG	CTC	CTG	GGG	CTC	CTG	CTG	CTC	TGG	CTC	CCA	GGT	GCA	CGA	
			9			18			27					36		45		54		
C	E	S	V	L	T	Q	P	P	S	V	S	G	A	P	G	Q	K	V	T	I
TGT	GAG	TCT	GTC	CTG	ACA	CAG	CCG	CCC	TCA	GTG	TCT	GGG	GCC	CCA	GGG	CAG	AAG	GTC	ACC	ATC
	63			72			81			90			99			108			117	
S	C	T	G	S	T	S	N	I	G	G	Y	D	L	H	W	Y	Q	Q	L	P
TCG	TGC	ACT	GGG	AGC	ACC	TCC	AAC	ATT	GGA	GGT	TAT	GAT	CTA	CAT	TGG	TAC	CAG	CAG	CTC	CCA
	126			135			144			153			162			171			180	
G	T	A	P	K	L	L	I	Y	D	I	N	K	R	P	S	G	I	S	D	R
GGA	ACG	GCC	CCC	AAA	CTC	CTC	ATC	TAT	GAC	ATT	AAC	AAG	CGA	CCC	TCA	GGA	ATT	TCT	GAC	CGA
	189			198			207			216			225			234			243	
F	S	G	S	K	S	G	T	A	A	S	L	A	I	T	G	L	Q	T	E	D
TTC	TCT	GGC	TCC	AAG	TCT	GGT	ACC	GCG	GCC	TCC	CTG	GCC	ATC	ACT	GGG	CTC	CAG	ACT	GAG	GAT
	252			261			270			279			288			297			306	
E	A	D	Y	Y	C	Q	S	Y	D	S	S	L	N	A	Q	V	F	G	G	G
GAG	GCT	GAT	TAT	TAC	TGC	CAG	TCC	TAT	GAC	AGC	AGC	CTG	AAT	GCT	CAG	GTA	TTC	GGA	GGA	GGG
	315			324			333			342			351			360			369	
T	R	L	T	V	L	G	Q	P	K	A	A	P	S	V	T	L	F	P	P	S
ACG	CGG	CTG	ACC	GTC	CTA	GGT	CAG	CCC	AAG	GCT	GCC	CCC	TCG	GTC	ACT	CTG	TTC	CCG	CCC	TCC
	378			387			396			405			414			423			432	
S	E	E	L	Q	A	N	K	A	T	L	V	C	L	I	S	D	F	Y	P	G
TCT	GAG	GAG	CTT	CAA	GCC	AAC	AAG	GCC	ACA	CTG	GTG	TGT	CTC	ATA	AGT	GAC	TTC	TAC	CCG	GGA
	441			450			459			468			477			486			495	
A	V	T	V	A	W	K	A	D	S	S	P	V	K	A	G	V	E	T	T	T
GCC	GTG	ACA	GTG	GCC	TGG	AAG	GCA	GAT	AGC	AGC	CCC	GTC	AAG	GCG	GGA	GTG	GAG	ACC	ACC	ACA
	504			513			522			531			540			549			558	
P	S	K	Q	S	N	N	K	Y	A	A	S	S	Y	L	S	L	T	P	E	Q
CCC	TCC	AAA	CAA	AGC	AAC	AAC	AAG	TAC	GCG	GCC	AGC	AGC	TAC	CTG	AGC	CTG	ACG	CCT	GAG	CAG
	567			576			585			594			603			612			621	
W	K	S	H	R	S	Y	S	C	Q	V	T	H	E	G	S	T	V	E	K	T
TGG	AAG	TCC	CAC	AGA	AGC	TAC	AGC	TGC	CAG	GTC	ACG	CAT	GAA	GGG	AGC	ACC	GTG	GAG	AAG	ACA
	630			639			648			657			666			675			684	
V	A	P	T	E	C	S</														

FIGURE 5b

Length of 16C10 heavy/primatized: 1431 bp;
 Listed from: 1 to: 1431;
 Translated from: 1 to: 1429 (Entire region);
 Genetic Code used: Universal; Fri, May 26, 1995 11:08 AM

Frame 1 M K H L W F F L L L V A A P R W V L S
 ATG AAA CAC CTG TGG TTC TTC CTC CTC CTG GTG GCA GCT CCC AGA TGG GTC CTG TCC
 9 18 27 36 45 54

Q V Q L Q E S G P G L V K P S E T L S L T
 CAG GTG CAG CTG CAG GAG TCG GGC CCA GGA CTG GTG AAG CCT TCG GAG ACC CTG TCC CTC ACC
 63 72 81 90 99 108 117

C A V S G G S I S G G Y G W G W I R Q P P
 TGC GCT GTC TCT GGT GGC TCC ATC AGC GGT GGT TAT GGC TGG GGC TGG ATC CGC CAG CCC CCA
 126 135 144 153 162 171 180

G K G L E W I G S F Y S S S G N T Y Y N P
 GGG AAG GGG CTG GAG TGG ATT GGG AGT TTC TAT AGT AGT AGT GGG AAC ACC TAC TAC AAC CCC
 189 198 207 216 225 234 243

S L K S Q V T I S T D T S K N Q F S L K L
 TCC CTC AAG AGT CAA GTC ACC ATT TCA ACA GAC ACG TCC AAG AAC CAG TTC TCC CTG AAG CTG
 252 261 270 279 288 297 306

N S M T A A D T A V Y Y C V R D R L F S V
 AAC TCT ATG ACC GCC GCG GAC ACG GCC GTG TAT TAC TGT GTG AGA GAT CGT CTT TTT TCA GTT
 315 324 333 342 351 360 369

V G M V Y N N W F D V W G P G V L V T V S
 GTT GGA ATG GTT TAC AAC AAC TGG TTC GAT GTC TGG GGC CCG GGA GTC CTG GTC ACC GTC TCC
 378 387 396 405 414 423 432

S A S T K G P S V F P L A P S S K S T S G
 TCA GCT AGC ACC AAG GGC CCA TCG GTC TTC CCC CTG GCA CCC TCC TCC AAG AGC ACC TCT GGG
 441 450 459 468 477 486 495

G T A A L G C L V K D Y F P E P V T V S W
 GGC ACA GCG GCC CTG GGC TGC CTG GTC AAG GAC TAC TTC CCC GAA CCG GTG ACG GTG TCG TGG
 504 513 522 531 540 549 558

N S G A L T S G V H T F P A V L Q S S G L
 AAC TCA GGC GCC CTG ACC AGC GGC GTG CAC ACC TTC CCG GCT GTC CTA CAG TCC TCA GGA CTC
 567 576 585 594 603 612 621

Y S L S S V V T V P S S S L G T Q T Y I C
 TAC TCC CTC AGC AGC GTG GTG ACC GTG CCC TCC AGC AGC TTG GGC ACC CAG ACC TAC ATC TGC
 630 639 648 657 666 675 684

N V N H K P S N T K V D K K A E P K S C D
 AAC GTG AAT CAC AAG CCC AGC AAC ACC AAG GTG GAC AAG AAA GCA GAG CCC AAA TCT TGT GAC
 693 702 711 720 729 738 747

K T H T C P P C P A P E L L G G P S V F L
 AAA ACT CAC ACA TGC CCA CCG TGC CCA GCA CCT GAA CTC CTG GGG GGA CCG TCA GTC TTC CTC
 756 765 774 783 792 801 810

F P P K P K D T L M I S R T P E V T C V V
 TTC CCC CCA AAA CCC AAG GAC ACC CTC ATG ATC TCC CGG ACC CCT GAG GTC ACA TGC GTG GTG
 819 828 837 846 855 864 873

V D V S H E D P E V K F N W Y V D G V E V
 GTG GAC GTG AGC CAC GAA GAC CCT GAG GTC AAG TTC AAC TGG TAC GTG GAC GGC GTG GAG GTG

FIGURE 5b (Continued)

882	891	900	909	918	927	936
H N A K T K P R E E Q Y N S T Y R V V S V						
CAT AAT GCC AAG ACA AAG CCG CGG GAG GAG CAG TAC AAC AGC ACG TAC CGT GTG GTC AGC GTC						
945	954	963	972	981	990	999
L T V L H Q D W L N G K E Y K C K V S N K						
CTC ACC GTC CTG CAC CAG GAC TGG CTG AAT GGC AAG GAG TAC AAG TGC AAG GTC TCC AAC AAA						
1008	1017	1026	1035	1044	1053	1062
A L P A P I E K T I S K A K G Q P R E P Q						
GCC CTC CCA GCC CCC ATC GAG AAA ACC ATC TCC AAA GCC AAA GGG CAG CCC CGA GAA CCA CAG						
1071	1080	1089	1098	1107	1116	1125
V Y T L P P S R D E L T K N Q V S L T C L						
GTG TAC ACC CTG CCC CCA TCC CGG GAT GAG CTG ACC AAG AAC CAG GTC AGC CTG ACC TGC CTG						
1134	1143	1152	1161	1170	1179	1188
V K G F Y P S D I A V E W E S N G Q P E N						
GTC AAA GGC TTC TAT CCC AGC GAC ATC GCC GTG GAG TGG GAG AGC AAT GGG CAG CCG GAG AAC						
1197	1206	1215	1224	1233	1242	1251
N Y K T T P P V L D S D G S F F L Y S K L						
AAC TAC AAG ACC ACG CCT CCC GTG CTG GAC TCC GAC GGC TCC TTC TTC CTC TAC AGC AAG CTC						
1260	1269	1278	1287	1296	1305	1314
T V D K S R W Q Q G N V F S C S V M H E A						
ACC GTG GAC AAG AGC AGG TGG CAG CAG GGG AAC GTC TTC TCA TGC TCC GTG ATG CAT GAG GCT						
1323	1332	1341	1350	1359	1368	1377
L H N H Y T Q K S L S L S P G K .						
CTG CAC AAC CAC TAC ACG CAG AAG AGC CTC TCC CTG TCT CCG GGT AAA TGA						
1386	1395	1404	1413	1422	1431	

Figure 6

Competitive Binding of CTLA-4Ig-Biotin to B7-1 Transfected CHO Cells
in Presence of P16C10 MAb, CTLA-4Ig and B7-1Ig Fusion Proteins

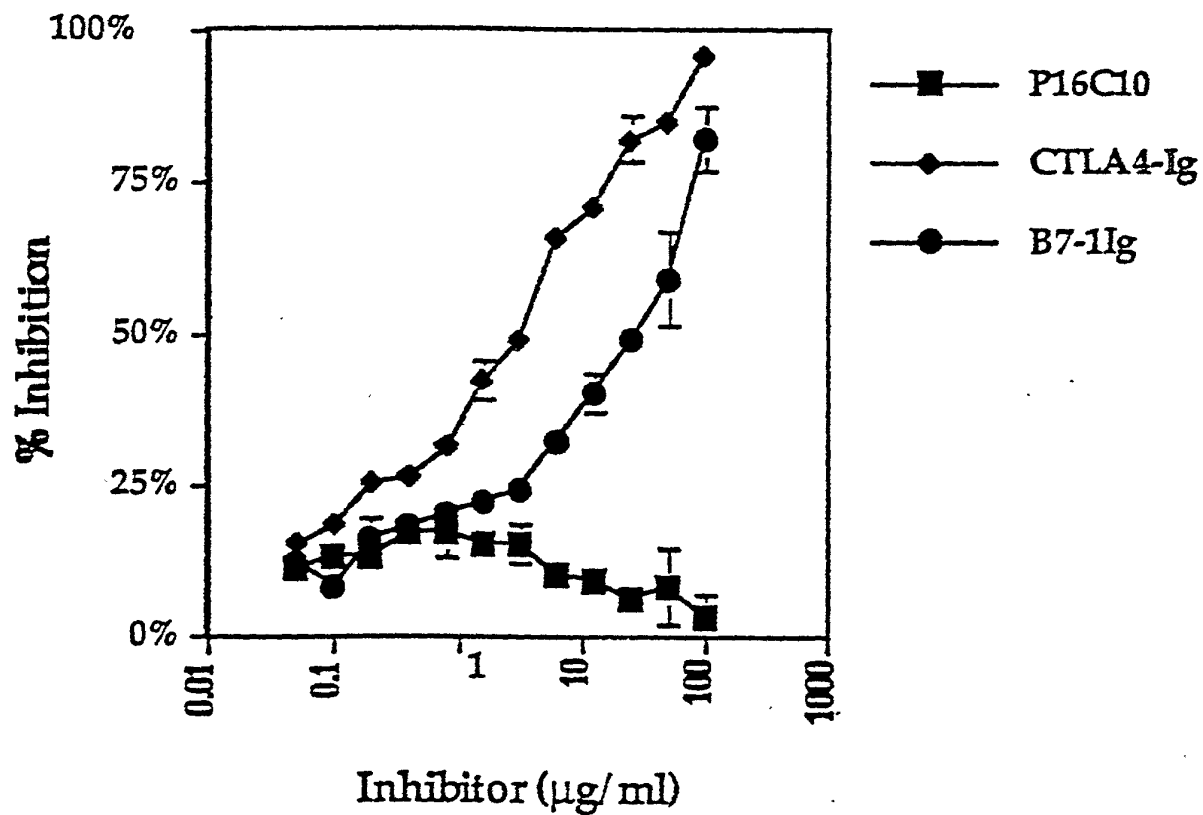


Figure 7

Competitive Binding of P16C10-Biotin to B7-1 Transfected CHO Cells
in Presence of P16C10 MAb, CTLA-4Ig and B7-1Ig Fusion Proteins

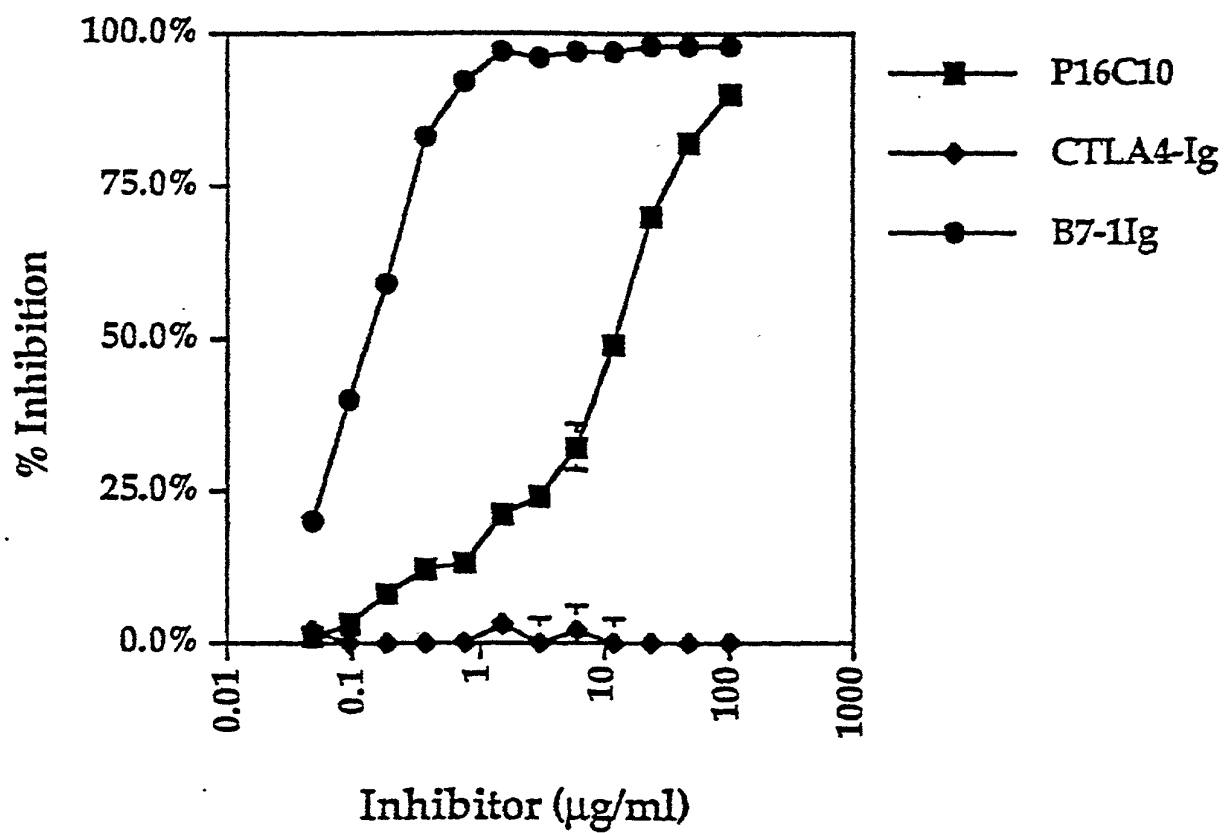


Figure 8

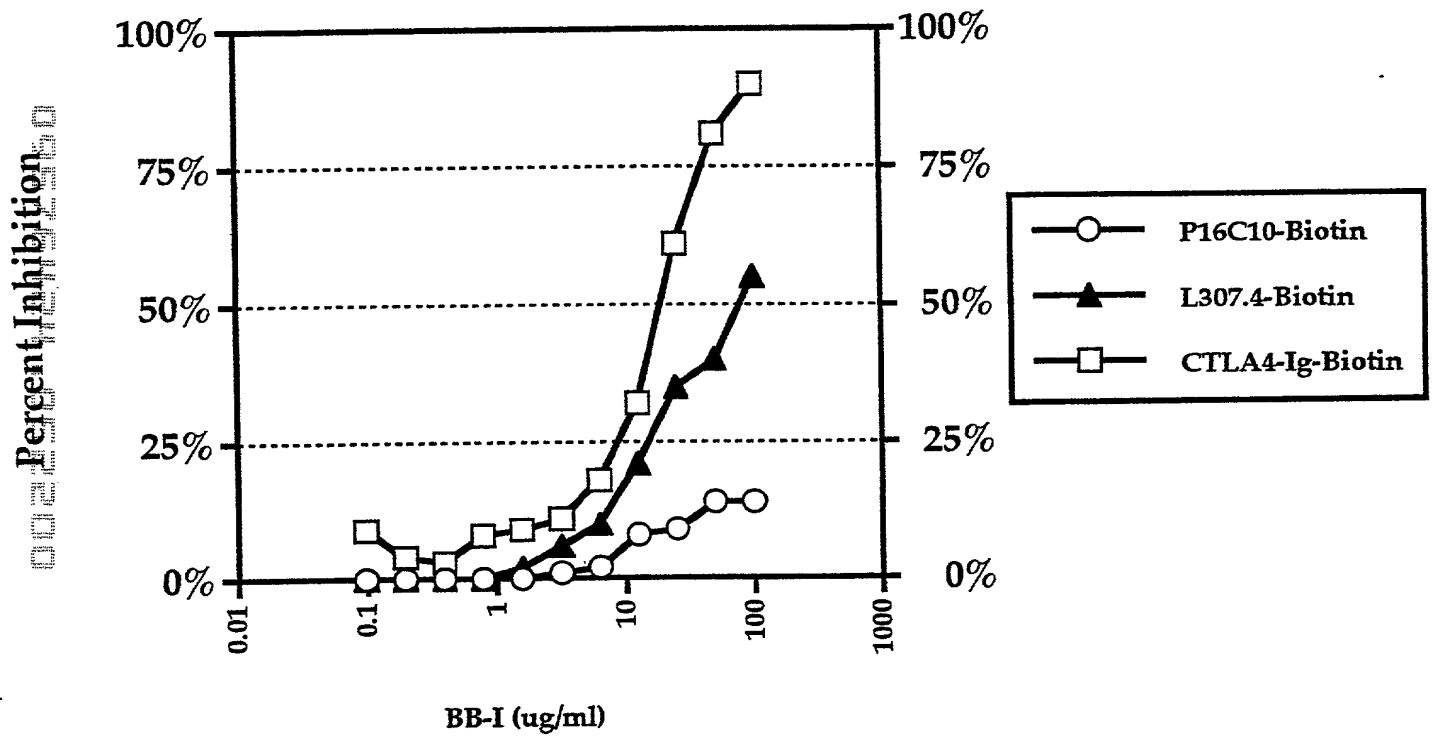


Figure 9

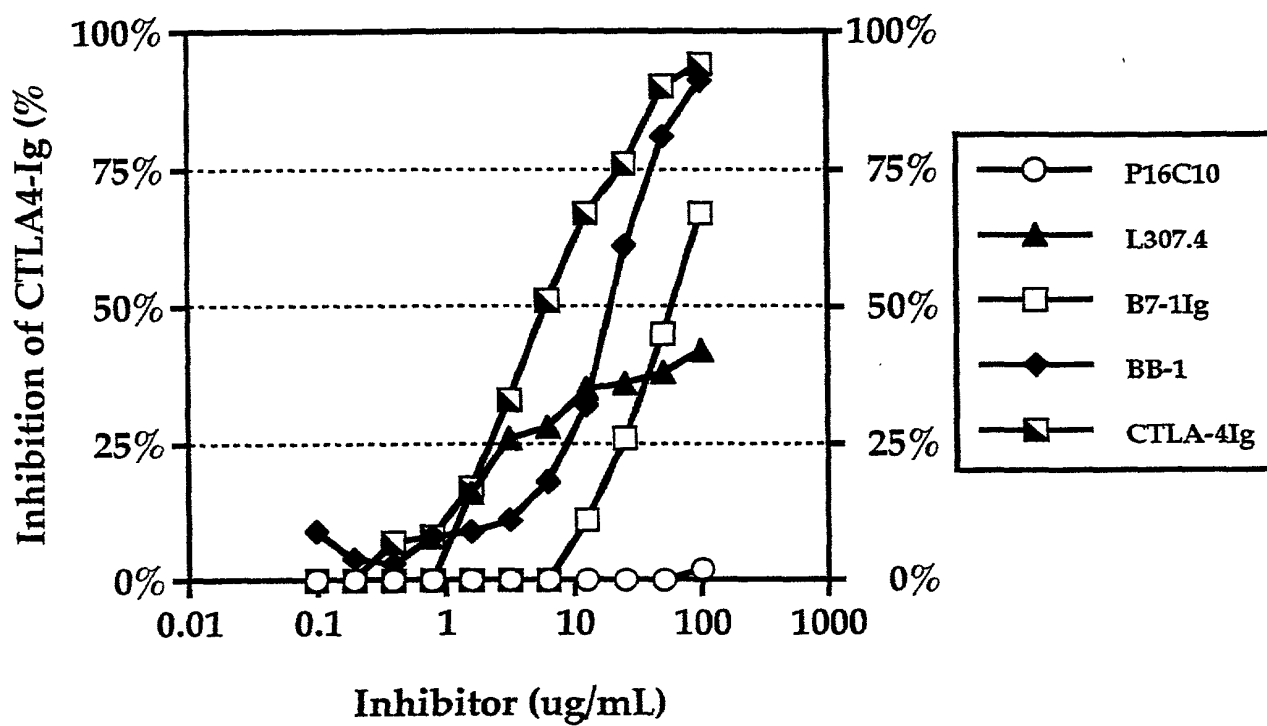
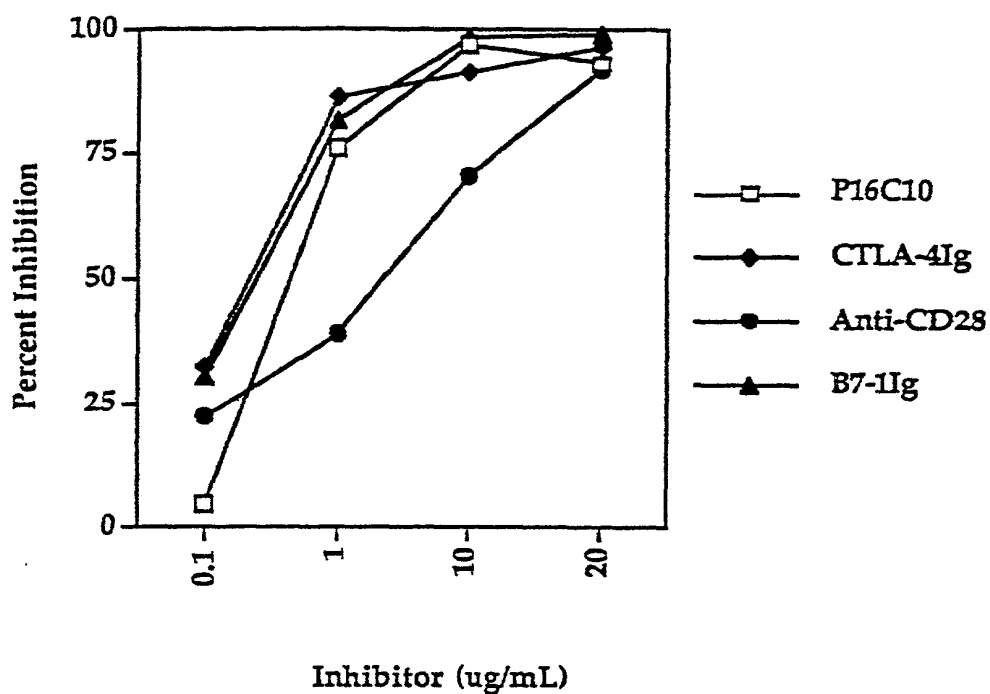
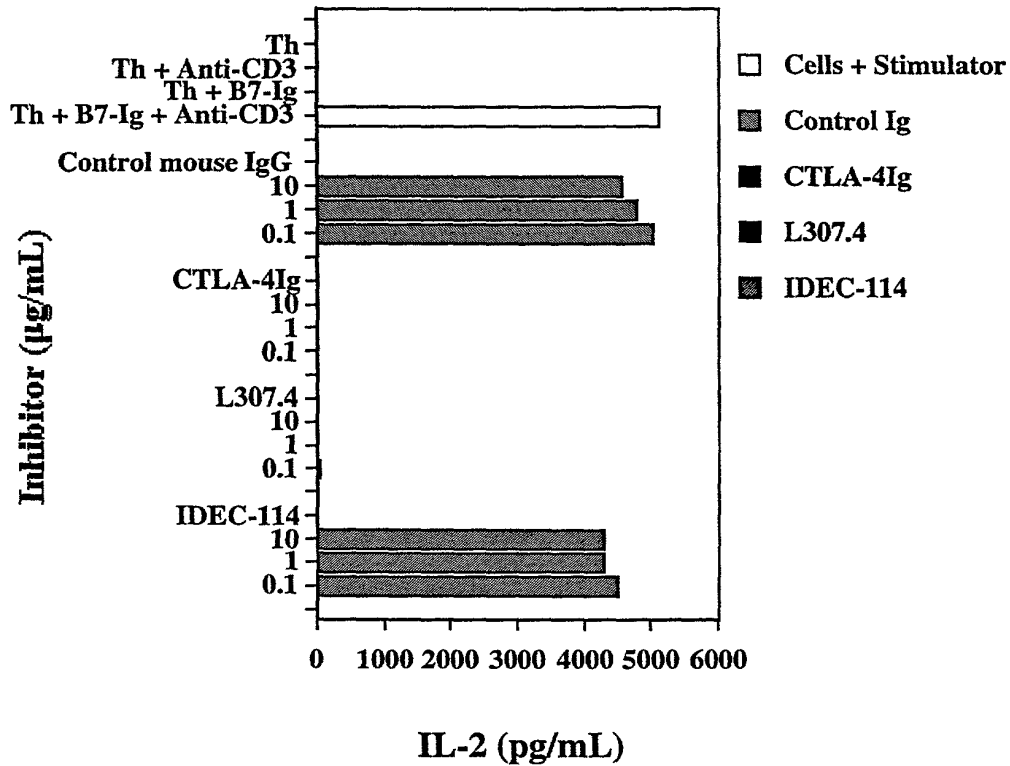


Figure 10

Competitive Inhibition of Radiolabeled B7-1Ig Binding to CD28 Receptors on Isolated Non-Activated Peripheral Blood T Cells using Unlabeled Binding Proteins Recognizing Either B7-1 or CD28



IDEC-114 Does Not Block IL-2 Production Induced by Co-stimulation with Anti-CD3 and B7Ig Coated Latex Microspheres



Figure/1: Production of IL-2 in cultures of purified normal human CD4+ lymphocytes when stimulated with sub-optimal amounts of immobilized anti-CD3 antibody and B7-1 (CD80) on latex microbeads. L307.4 is a commercially available murine antibody (B/D Pharmingen) that binds specifically to human CD80 and neutralizes CD28:CD80 functional interactions. CTLA-4Ig is a soluble receptor fusion protein that specifically blocks CD80 and CD86 binding to CD28 receptors on T cells. IDEC-114 is a PRIMATIZED monoclonal antibody that specifically binds to both soluble and membrane forms of the CD80 antigen but does not recognize CTLA-4 or B7-2 antigens. The ratio of anti-CD3 to B7Ig used in the cultures to stimulate T cells was 1:10 (w/w).

IDEC-114 Does Not Block T cell Growth When Co-stimulated by Anti-CD3 and B7Ig Coated Latex Microspheres

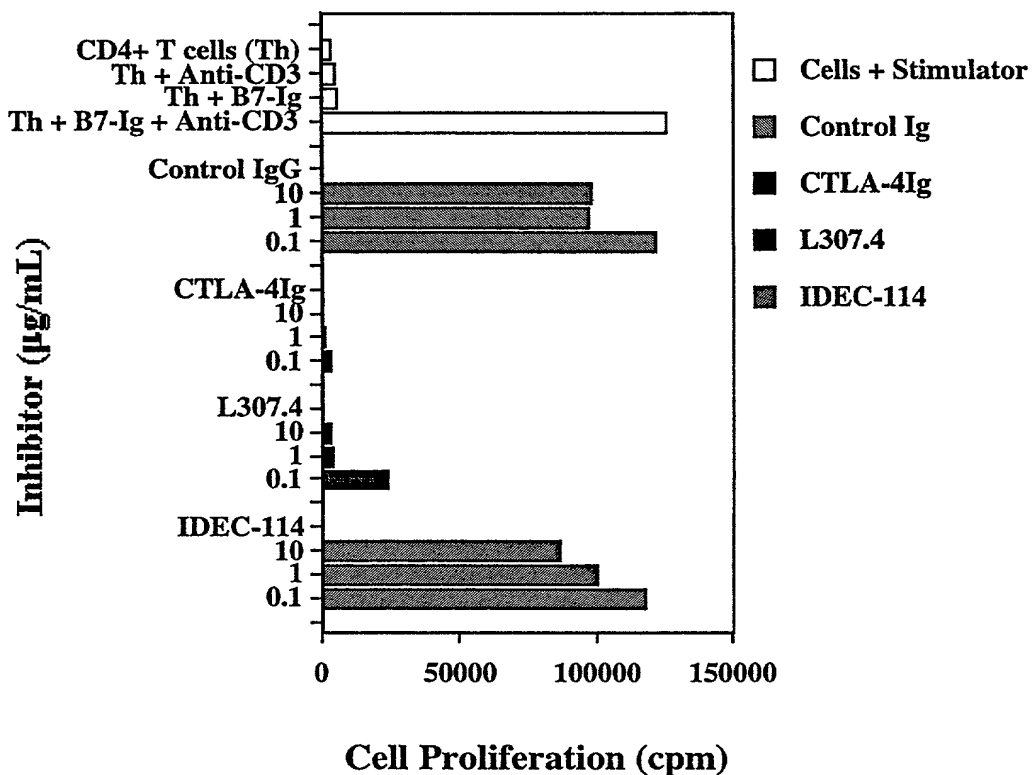


Figure 2: Uptake of H3-Thymidine in cultures of purified normal human CD4+ lymphocytes when stimulated with sub-optimal amounts of immobilized anti-CD3 antibody and B7-1 (CD80) on latex microbeads. L307.4 is a commercially available murine antibody (B/D Pharmingen) that binds specifically to human CD80 and neutralizes CD28:CD80 functional interactions. CTLA-4Ig is a soluble receptor fusion protein that specifically blocks CD80 and CD86 binding to CD28 receptors on T cells. IDEC-114 is a PRIMATIZED monoclonal antibody that specifically binds to both soluble and membrane forms of the CD80 antigen but does not recognize CTLA-4 or B7-2 antigens.

Production of IL-10 by Co-stimulation with Anti-CD3:B7-Ig (1:10) Latex Microspheres is Inhibited by CTLA-4Ig, and Anti-CD80 Antibodies L307.4 and IDEC-114

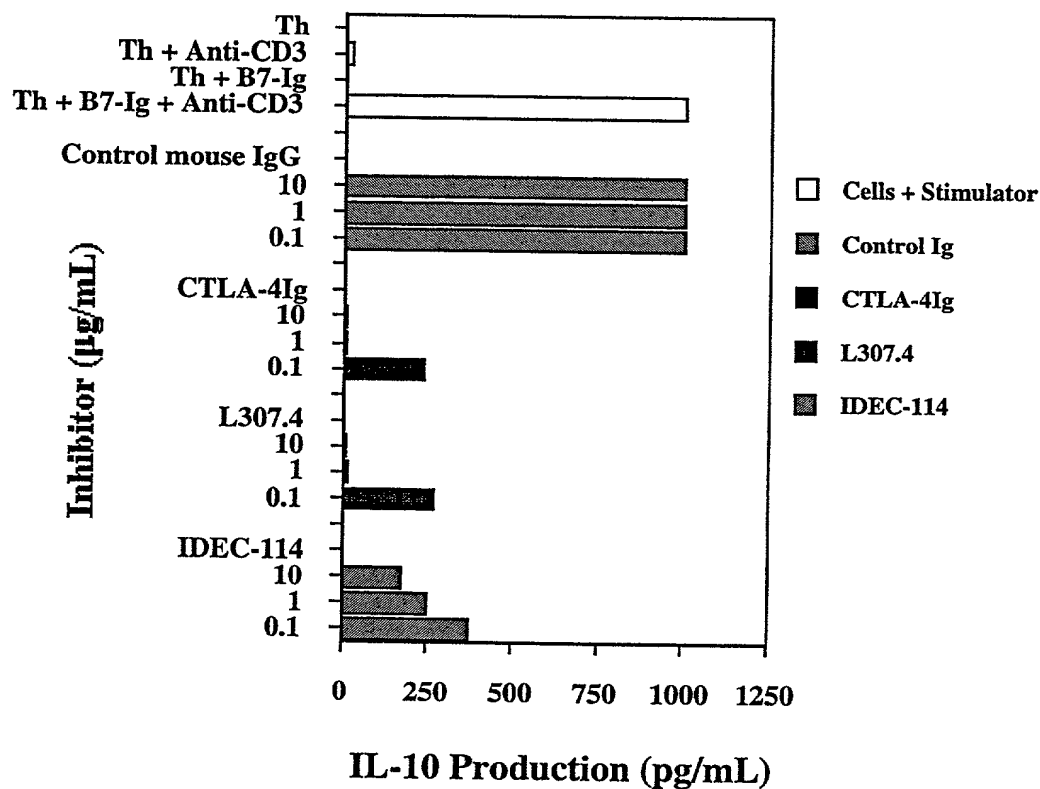


Figure 3: Production of TH2 cytokine IL-10 in cultures of purified normal human CD4+ lymphocytes when stimulated with sub-optimal amounts of immobilized anti-CD3 antibody and B7-1 (CD80) on latex microbeads. Inhibition of IL-10 production by L307.4 anti-CD80 and CTLA-4Ig fusion protein was compared at 0.1, 1, and 10 µg/mL.

**IDEC-114 Blocks IL-2 Production by Purified CD4+ T Cells
When Low Bead Densities of B7 are Used as Stimulators**

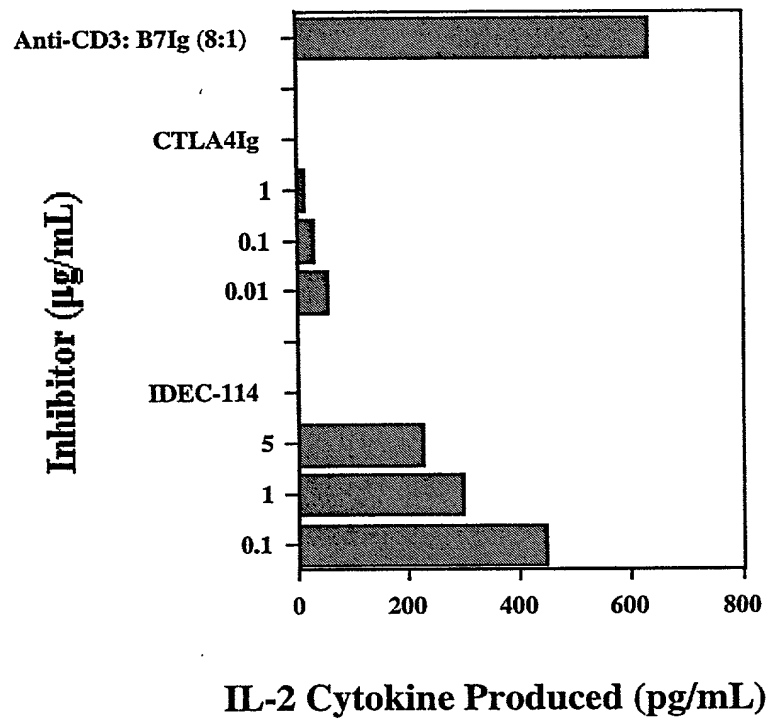


Figure 4: Inhibition of IL-2 cytokine production by CTLA-4Ig and IDEC-114 in cultures of purified human CD4+ T cells. T cells were co-stimulated with anti-CD3 and B7Ig coated latex microbeads with an anti-CD3/B7 ratio (w/w) of 8:1. IL-2 was determined by growth and uptake of Thymidine by the IL-2 dependent cell line CTLL-2.